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Miniature Infrared Sources for Spectroscopy Applications

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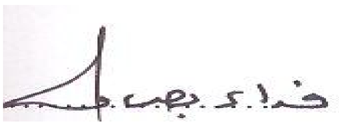
Dedication

To my True Love, My Family:
My beloved Mother,
Supporting Brothers
And nice Sisters
With Great Love

Fida Mosa Issa Buss

Declaration:

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed: 

Fida Mosa Issa Buss

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Abstract

Infrared (IR) spectroscopy is an important branch of physics, used for many different and useful applications. The present work investigates the possibility to construct miniature IR sources from readily available materials and examine their characteristics and potential use in spectroscopic applications. IR sources were constructed from a Fecralloy sheet to get two sided emitting sources of different lengths and widths, characteristics of such sources were studied by a construction of a simple experimental set up to get such pulsed infrared sources and to achieve the self cooling process.

Another miniature IR source was performed is a Nichrome wire formed in a helix shape, this source was compared to the Fecralloy sources. The used miniature source was made from inexpensive available material and can be easily constructed to be used in different types of applications instead of heavy expensive other infrared sources.

As the emitted infrared power is very small, and in order to benefit from such radiation; different types of focusing methods were used from inexpensive available devices such as a hemispherical shape, a honey comb mesh, an Al radiation guiding tube and a reflective mirror. It was found that the method of Al guiding tube was the best method specially at small distances, even though the reflective mirror is the most sensitive and expensive one; it's focusing was the least.

Finally; different applications which can be improved to be used in advanced ones and important uses were constructed such as liquid absorption of IR radiation in which different types of liquids were compared according to their infrared absorption. Studying the effect of heat on vegetable oil properties is another important application which was used. Dependence of dye of same color but different concentration and the detection of olive oil adulteration with vegetable oil are another two performed applications.

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List of Abbreviations:

Symbol	abbreviation representation
FEL	Free electron laser
FIR	Far infrared radiation
FTIR	Fourier transformed IR
IR	Infrared radiation
LAN	Local area network
LED	Light emitting diode
MIR	Mid infrared radiation
NIR	Near infrared radiation
OTIM	Optical transform image modulation
QC	Quantum cascade laser
SFB	Semiconductor film bolometer

Chapter one

Historical background

1.1 Introduction

Optics containing electromagnetic radiation which is an exciting and important field of physics has been utilized widely. Infrared is an electromagnetic radiation which has same main properties of reflection, such as the transmission through the fiber optics through the total internal reflections, diffusion, refraction, diffraction and polarization as that of light (Standel et al, 1963). It lies just beyond the end of the red visible light and can be produced at the same time with the visible light from most kinds of light sources (Bryant et al, 1992). The reason for interest and focusing on infrared spectral region is the application-dependent on the IR radiation. Sun is the earliest infrared source with half of its radiation lies in the infrared beyond wave length of 700nm (Sargent, 2008).

All objects with temperature larger than the absolute zero degree (-273.15°C) are able to emit electromagnetic radiation (Wang et al, 2003), widely infrared sources are easily found; in designing such sources; large spectral ranges and different working temperatures are desired to get a well-characterized and trustable one (Palchetti et al, 2007). Basically; there have been four kinds of infrared sources which are: Nernst Glower which operates at 200Watts, 60 amperes and at 1500 to 1950K, globar that needs a flow of water for cooling the housing and operates at 200watts, 6 amperes and a temperature of 1470K, gas mantle in which the pollution of the gaseous fuel and the output spectrum in far IR from the curve of the blackbody are two disadvantages of this type and Tungsten filament lamp in which the envelope material is a quartz and this will limit the spectral emission to 3 microns maximum (Boland et al, 1995).

The traditional source in IR absorption spectroscopy is a glowing rod or wire heated by the passage of an electric current (Levine, 1975). Ceramic blackbody radiator is a common infrared source with a widely spread power on wavelength band. Such a source is used in photoacoustic effect (Uotila, 2007). Tungsten filament lamp with glass envelope was used as an infrared source (Smith et al, 1997). Common used infrared sources are lasers which can be electrically amplitude modulated such as diode lasers which are limited to near and shortwave infrared spectral region, quantum cascade lasers (QC) which produce a lot of power at the mid-and long-wave infrared wavelength regions and gas lasers. Such lasers are used in photoacoustic due to their narrow line-width. Wavelengths of QC and diode lasers are tuned precisely (Uotila, 2007). Diodes are infrared luminescent sources made of sensitive infrared radiation (Nash et al, 2004). Another type of IR sources is the pulsed mid-IR thermal source which is based on electrical heating of a thin metal alloy foil followed by self cooling process, examples of these alloy foils are Fecralloy (Lainé et al, 1997).

After the discovery of IR radiation; scientists improved many types of detectors each of which detect certain types of sources (Suszyn´ski et al, 2004), the most important task of detectors is the increase of the detected radiation signal with contrast to the pre-exposure which results in changing responsivity of the detector (Roth et al, 1996). High resolution and detectivity are needed in most applications (Liu et al, 1994), so; improvement of highly sensitive, inexpensive and uncooled thermal detectors has increasingly become general direction importance in the infrared sensing field (Noda et al, 2001). For example; in thermal detectors; detecting small temperature will lead to a variation in voltage, resistance or capacitance (Ziegler, 1983).

One of the thermal wave methods in infrared detection with dynamic induction heating is Registration of infrared camera used as a variant of time-resolved thermography after inducing eddy currents in studied object (Suszyn´ski et al, 2004). For detectors such as bolometers; the absorption of the infrared radiation will increase the temperature, this results in an increase of the resistance of the detector producing a voltage across the detector (Bo-Qi et al-QI, 1991). Thermopiles are the most inexpensive and favored when lower performance is acceptable (Dann, 1994). The Golay cell was the most common detector used in the early days (Martin, 1980). Photoconductors or photovoltaics are types of detectors used for IR FELs. At longer wavelengths higher power levels pyroelctric detectors are used (Kimmitt et al, 1996). Pyroelectric detector is used in IR absorption spectroscopy and requires a modulated (switch on and off) incident power (Fairley et al, 2001). Photon drag detectors can be used at room temperature (Kimmitt et al, 1996). In the mid infrared range the most sensitive detectors are formed with narrow gap semiconductors and fabricated for great passive thermal applications (Arnold et al, 2005).

As IR can be produced from light sources it has different colors depending on the magnitude of the absorption process that is materials can be distinguished by measuring their IR absorption; type and number of molecules can be known depending on the amount of absorbed radiation, chemical substances can be distinguished according to their different absorption properties (Bryant et al, 1992). Near and mid infrared spectroscopy are used widely in different fields. One can determine the most suitable radiation for an application depending on the absorption bands and due to the intensity of radiation (Rabie et al, 2001). Infrared spectroscopy is one of the analytical techniques available to measure the absorption or emission of radiation as a consequence of vibrations within a molecule between the compound atoms (Workman, 1988). IR emission spectroscopy is an effective alternative method for the study of low frequency vibrational modes (Brown et al, 1995).

Determining the radiation in emission spectroscopy; measurement of a familiar source of radiation treated as a blackbody cavity is necessary and is given by the Planck law of radiation. To approach a well-characterized emission; three points are required in designing a blackbody reference source: a low reflectance coefficient in the whole frequency range, known and uniform temperature and maximum number of internal reflections (Palchetti et al, 2007). As it has many types of sources; IR radiation can be used widely in different fields of life. It can be used to measure the concentration of liquids and gases. LEDs can be used in monitoring of gases (Bryant et al, 1992).
Infrared optical devices were used in increasing the amount of the infrared detected radiation such as infrared focusing lens and a collimator (Lee et al, 2007).

Infrared spectral range is one of the interesting radiations and technological importance which related to its sources since infrared is thermal or in other words every heated object can emit infrared radiation so it's easy and wisely to benefit from these radiations.

1.2 Statement of the problem

Electromagnetic radiation has wide range of applications, especially from ultraviolet to near infrared region. But for longer wavelengths between the near-infrared and the microwave spectral regions, fewer options are available since spectrum is under development (Nahata et al, 2002). Infrared radiation can be extracted easily from available sources. To do so; infrared sources can be used, and advantages such as selectivity, wide sensitivity of IR sources make it the preferred technology (Smith et al, 1997). It does not matter how much big nor what shapes are they, but small, inexpensive, easily mobile and simply fabricated sources are desired. To get better results in any application; one must study the characteristics of different shapes of those sources concerning many aspects.

Many sources were used in different applications, but miniature sources are favorable, according to their size and cost. Such sources like pulsed Fecralloy are easily fabricated from small sized thin foils. An available Nichrome wire was used also in this research. For any application; Detectors used must be also suitable to the given source.

Because Pulsed IR sources were used; a pyroelctrical detector was used since it needs a modulated power. To avoid vibrational noise generated in mechanical chopping; function generator was used as an electrical power to modulate the sources. With easily controlled chopping frequency and smaller physical size of the system.

Small devices with soft reflecting coating materials with low cost and physical flexibility can be used as simple active reflectors. Such devices can be used to benefit from the reflection properties of infrared radiation, and the result is a magnification of the detected radiation using miniature sources that can be used in simple applications which can be improved to complex useful applications in different fields of life. In general, our problem is to construct from available material miniature infrared self cooled pulsed sources suitable for spectroscopy and many other applications.

1.3 Importance of the study

This research is performed in order to benefit from miniature infrared sources. Those small, inexpensive, easily fabricated from available material can be improved by different methods to be used in infrared spectroscopy instead of large expensive sources. An additional advantage of the miniature IR sources is the construction of portable handy gas detection systems.

1.4 Objectives of the study

Main purposes of this study are to:

1) Construct, perform miniature, inexpensive and available infrared sources.
2) Study the characteristics of the constructed sources.

3) Enhance infrared radiation from such sources by employing focusing and reflection methods.
4) Use some of the miniature IR sources in some applications.

1.5 Hypothesis

1) Miniature infrared sources can be used equivalently with other sources.
2) Available, small, and inexpensive reflecting devices can be used to focus radiation so that the detected infrared flux from sources is enhanced.
3) Simple applications can be performed to benefit from miniature sources.

Chapter Two

Theoretical background

2.1 Introduction

Optics field of physics has real and important wide range and essential array of technological applications, electromagnetic spectrum which is an optical radiation from ultraviolet, visible and near-infrared regions have been widely used as the result of the existence of the coherent optical sources and sensitive detectors. On the other hand; as we move to longer wave lengths from near-infrared to microwave spectral regions one finds that fewer options are available, this region of spectrum is under development (Nahata et al, 2002).

As visible light and ultraviolet; infrared can be transmitted in the form of "beams" which can be bent by reflection or by diffraction in a prism. In this method (diffraction of a prism) IR radiation was discovered, and because IR radiation is widely spread; one must benefit from sources of such radiation. This chapter will discuss the main topics of subjects of the thesis; IR Spectrum, IR sources, with small attention to IR sources which will be used, IR detectors and IR spectroscopy.

2.2 Infrared spectrum

Infrared is one of the most important electromagnetic radiations. The name of these radiations comes from the Latin word "infra" which means "below", and "red" which is the color of the visible light part having the longest wavelength, that is the least frequency (or energy), so that the whole word "infrared" means below red (http://en.wikipedia.org/wiki/Infrared, 2008).

Sir Frederick William Herschel in 1800, while studying how much heat passed through different colored filters by using thermometers, used a prism to refract light from the sun or on other words to create a spectrum. He measured the temperature of each color. To achieve this; he used three thermometers with blackened bulbs (to better absorb the heat) and placed one bulb in each color while the other two were placed beyond the spectrum as control samples. As he measured the temperatures of the violet, blue, green, yellow, orange and red light, he noticed an increase in the temperature recorded and that the temperature of the colors increased from the violet to the red part of the spectrum, and the temperature of the region just beyond the red part of the spectrum has the largest temperature (Levine, 1975). It can be said that infrared radiation which is a part of electromagnetic waves nominally extending from the visible (approximately 700nm) to just before the microwave region practically defined as approximately 200μm (Workman, 1988).

Infrared radiations (IR) are abundant; this is related to their widely spread sources, as infrared is emitted from molecules if they have finite temperature, these molecules will rotate and vibrate producing phonons. In IR region the dielectric response and conductivity of materials is very important for ultrahigh-frequency electronics (Nahata et al, 2002). Our bodies, filament lamp, earth and stars even animals can emit IR radiation. So it is to say that all bodies at finite temperature will emit radiation as indicated by the law of black body radiation (Smith, 2002).

As indicated before for every heated body a spectral distribution of the radiant energy will be emitted and the power density of IR radiation emitted in unit area by a black body according to Planck's radiation law (Elmer, 1982) and (Smith, 2002):

$$p(\lambda) = \frac{hc^2}{\lambda^3}\frac{d\lambda}{e^{hc/\lambda kT}-1} \tag{2.1}$$

Where h, k and c are Planck's constant, Boltzmann's constant and the speed of light respectively. T is the temperature and λ is the wavelength.

From Planck's radiation formula; other relationships for a black body spectrum can be derived. The Stefan Boltzmann law gives the flow of radiation energy $\dot{q}$ emitted from a black body as a function of the black body temperature:

$$\dot{q} = \varepsilon\sigma_{SB}T_{mem}^4 \tag{2.2}$$

With $\sigma_{SB}$is the Stephan-Boltzmann constant, $T_{mem}$is the temperature of the hot surface, ε and is the emissivity (Schulz et al, 2005).

IR radiation can interact with matter by absorption of energy, either as direct or indirect measurements (Workman, 1988). When a system is subjected to radiation of frequency υ, or wave number k, there will be three processes which may occur:

1) Induced absorption in which the molecular (or atom) M absorbs a quantum of radiation and is excited from m to n:

$$M + hck \to M^* \tag{2.3}$$

This is the familiar absorption process.

2) Spontaneous emission, in which M^* (in state n) spontaneously emits a quantum of radiation:

$$M^* \to M + hck \tag{2.4}$$

3) Induced, or stimulated, emission. This is a different type of emission process from that of type 2 in that a quantum of radiation of wave number k given by:

$$\Delta E = E_n - E_m = h\upsilon = hck \tag{2.5}$$

Is the energy required to induce, or stimulate, M^* to go from n to m. the process is represented by:

$$M^* + hck \to M + 2hck \tag{2.6}$$

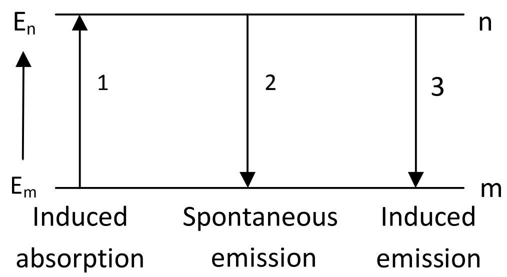


Fig. 2.1: Absorption and emission processes between states m and n.

For IR radiation; absorption and emission processes will depend on the type of the IR (Jones, 1997). To understand how does this occur and on what does it depend; IR subdivisions must be studied. These subdivisions depend on their uses, for example CIE (international commission on illumination) recommends to divide IR radiation into three bands: IR-A band with average 700nm-1400nm, IR-B band: 1400nm-3000nm, IR-C band: 3000nm-1mm. For Astronomers usually the IR spectrum is divided as: Near: (0.7-1) to 5μm, mid: 5 to 40 μm, long: (25-40) to 200-350 μm (http://en.wikipedia.org/wiki/Infrared, 2008). According to Roychoudhury et al, 2006; Infrared radiation can be divided according to the wavelength as: near infrared NIR (750-2500nm), mid infrared MIR (2500-40000nm) and far infrared FIR (40000-60000nm).

Usually IR region of electromagnetic spectrum is considered to be consisted of far IR [or (THz) which ranges from 0.1 THz to 10 THz (1 THz=10^{12}Hz=33.3cm^{-1}=4.1mev) with wavelengths from 3mm to 30 μm], mid IR which extends from microwave and near IR frequency with wavelengths from 30 μm to 2 μm (Nahata et al, 2002).

Traditionally; IR wavelengths are divided into three regions; the portion which is near the visible region is the near-IR: λ=0.8-2.5 μm; the mid IR which extends from 2.5 to 50 μm; and the far IR which extends from 50 to 1000 μm (Levine, 1975).

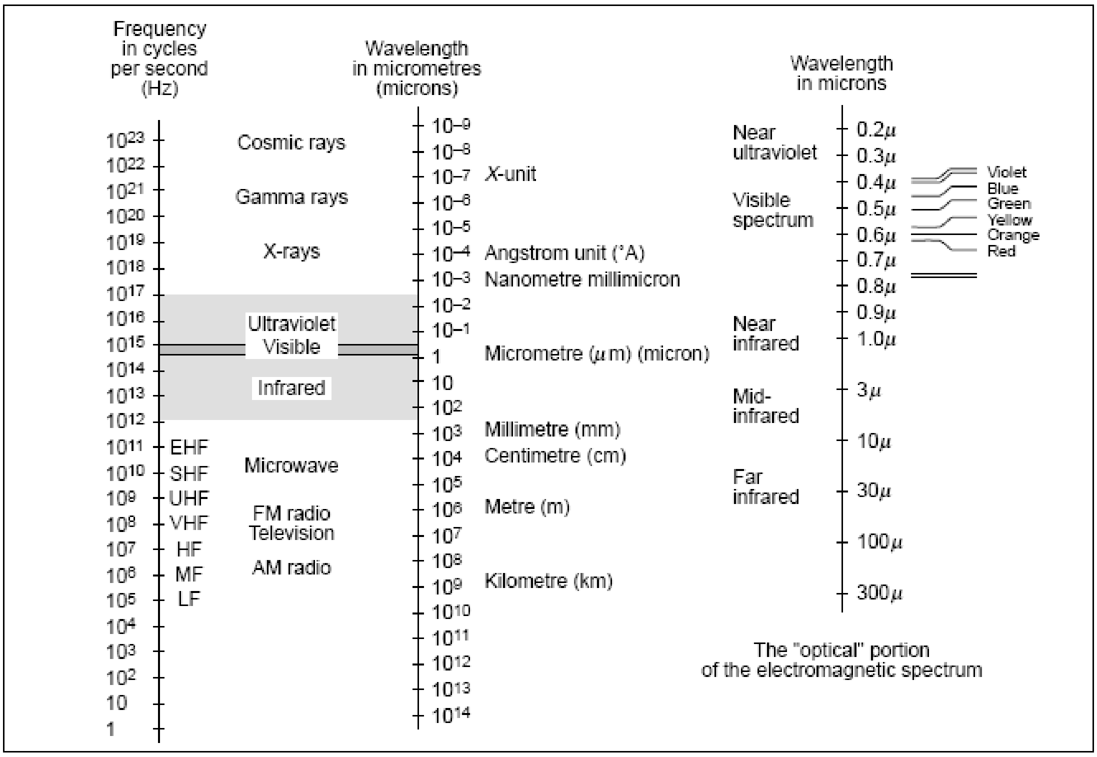


Fig. 2.2: Electromagnetic spectrum after (Dann, 1994).

In the far IR; pure rotational transitions of light molecules and low-frequencies vibrational transitions of heavy molecules occur (Levine, 1975). The near infrared spectral region is composed of absorptions related to vibrational overtones and combinations, to which absorptivity associated is less, by one or more orders of magnitude than the fundamental vibrational absorptions (Workman, 1988), Transitions between quantized vibrational energy states are the origin of the MIR. Spectrum of MIR exhibits high degree of spectral resolution than the NIR (Roychoudhury et al, 2006).

Variant ways are used to separate near infrared radiation at the suitable wavelengths which are in the range of 1000-2500nm. For example, diffraction grating and two beam interferometer or acousto-optical tunable filter are used to produce a full near- infrared spectrum (Hammond, 1997).

Spectral regions of near and short wavelengths infrared are used in wide applications such as in fiber-optics communications, night vision, biomedical imaging and efficient solar energy collection (Sargent, 2008) in communications; IR radiation for example can be considered as a suitable medium for short-range indoor communications like wireless LAN (local area network) systems; because its unregulated bandwidth is abundant and opaque barriers cannot be penetrated by it (Yang, 2000).

2.3 Infrared sources

After the discovery of IR radiation, astronomers found that sun emits IR radiation, many experiments done by scientists to find out if there is any other sources besides our sun or not! Many researches lead to the fact that any object with finite temperature can be considered as an electromagnetic radiation source but with different power depending on its temperature (Wang et al, 2003), Scientists decided to benefit from these wide sources so as to use them in applications. Year after year IR sources produced with different properties according to their applications.

As temperature of a body increases its thermal energy will increase and IR radiation will increase and thus this will give a better IR source, the brightness of a source which is very important in applications is the energy per unit volume (Smith, 2002). Hence, basically an IR source can be produced by allowing a current through a resistive element. One important practical problem needed to be solved is how to construct IR source that is pulsed and suitable for IR spectroscopy.

2.3.1 Traditional infrared sources:

The traditional source in IR absorption spectroscopy is a glowing rod or wire heated by the passage of an electric current, when a body becomes hot it radiates over a continuous frequency range. Prisms can be used to disperse these radiations like NaCl prism which is transparent over much of the IR region and it is commonly used (Levine, 1975). Grey bodies such as Glowbars which are rods of silicon carbide or Cesiwid glow-bar with emissivity of 0.8 and temperature of 1000 to 1500K (http://www.muller-elektronik-optik.de/es5.pdf, March 2009) or coils such as nichrome alloy resistance wire with high emissivity in the mid-infrared region; can be used as a blackbody source of temperature between 500K and 2000K (Dann, 1994). Those two types of sources can be used at frequencies (500-10000 cm^{-1}) where no shortage of energy exists in this region (Martin, 1980).

Nernst glower is a device made of a renitent material such as Thoria, and started after heated by a flame (Boland et al, 1995), its sintered mixtures of the oxides of Zr, Y, and Er (Kemp, 1987), was used as an infrared source to study the infrared fiber optics techniques (Standel et al, 1963). Beside Nernst glower, electrically heated rods such as Nernst various ceramic materials are sources that vary in intensity over the required frequency range

(Kemp, 1987), Ceramic blackbody radiator have a widely spread power on wavelength band such a source is used in photo-acoustic effect (Uotila, 2007).

Tungsten filament lamp with glass envelope and pulsed at 8 Hz and provides a modulation depth of ~40% can be considered as a blackbody with an emissivity of ~10% at 4μm at 2000K (Smith et al, 1997), the quartz glass envelopes of the lamp do not transmit radiation from the filament beyond 4 microns. Envelopes become hot and radiate across the spectrum as a source of temperature 400K (Dann, 1994). Other examples of lamp IR sources are a 200W quartz-iodine lamp with a coiled-coil filament that is performing at 3000K over a range of 0.25 to 2.6 μm (Stair et al, 1963). The light bulb with hot element carbon composite board was used also as an infrared source (Havstad et al, 1993), Deuterium lamps on the other hand can be used to produce a continuous spectrum from 190nm to 400nm (http://www.muller-elektronik-optik.de/es5.pdf, March 2009). However; the most generally used source for long wave instruments is the mercury lamp with silica envelope. The advantage of these lamps over hot body sources as the Nernst filament which consists of a mixture of rare earth oxides, or a silicon carbide Globar (Hollas, 1997) is that they emit a greater proportion of their total energy at longer wavelengths and less at shorter wavelengths, where stray radiation is usually noisy. Energy is radiated of the silica envelope of mercury lamp as it becomes hot in use, and transmitted from the plasma itself at frequencies below $100cm^{-1}$. In order to reduce the amount of radiated energy at shorter wavelengths; a water-cooled jacket may be used to surround the lamp. Bare tungsten coiled-coil filament is better than that of a mercury arc (Martin, 1980), clearly, the spectrum differs from one lamp to another with the envelope's part through which the discharge is being viewed (Emery et al, 1976).

Gas mantle is another type of sources which uses a gasoline fired mantle same as a camping lamp. This mantle is fabricated of thoria and heated to give a strong emission (Boland et al, 1995).

Modulation of blackbody radiator can be achieved using mechanical and electrical chopping. In order to reach low warm-up and cooling time for an electrically modulation; blackbody used must be very small (Uotila, 2007).

2.3.2. Light emitting diodes (LEDs):

Small size light emitting diodes LEDs emits IR at wavelengths absorbed by molecules and can be considered as incandescent sources (Bryant et al, 1992). For example, near infrared (1 to 1.3 μm) plastic light emitting diodes were created using conjugated polymers and indium arsenide-based nanocrystals (Tessler et al, 2002), on the other hand, an interband cascade light emitting diodes operates at 300 and 77 K with an output power up to 700nW in the 5-8μm spectrum region (Yang, 1997), it was found that LEDs with a power more than 3.5mW at room temperature are well matched to the CH_4 absorption spectrum and they were used as an infrared CH_4 gas sensor (Krier et al, 2000). By the time, unique light emitting diodes (LEDs) have been developed so that they radiate at exactly the IR wavelengths absorbed by molecules such as water (1.8 μm) (Bryant et al, 1992), these diodes when forward biased; emit more infrared radiation than they absorb. On the other hand; when reverse biased they emit radiation below the normal absorption rate (Nash et al, 2004); But with all their advantages; LEDs won't supersede tungsten lamp devices (Smith et al, 1997), Near Infrared emitting diodes as an infrared sources which are working at room temperature emits radiation up to 5μm, on the other hand; longer infrared emitting diodes (8-12μm) require cooling to be operated (Malyutenko et al, 2000).

2.3.3. Synchrotron as an infrared source:

A synchrotron is an IR source with IR radiation that comes as pulses with fairly short duty cycle. Its power/unit wavelength is less than 200K black body does. But, its pulses are brighter than that of a black body (smith, 2002) they are According to Williams 1982 between two and three orders of magnitude. A universal formula for calculating the IR brightness of storage rings (sr) of synchrotron can be expressed as:

$$B(\lambda) = \frac{75IBW/\lambda^3 W}{mm^2}/\text{sr} \tag{2.7}$$

Where λ is the wavelength in microns, I (A) is the current circulating in the synchrotron and BW is the bandwidth in percent. And the power radiated by synchrotron is given in the form of:

$$P(\lambda) = 8.7 \times 10^{-5} I\theta BW \times (\frac{\rho}{\lambda})^{\frac{1}{3}}/\lambda W \tag{2.8}$$

Where BW, λ and I are as before, and θ (rad) is the horizontal collection angle and ρ (same units as λ) is the synchrotron bend radius (Smith, 2002).

2.3.4. Lasers:

Laser is a coherent and directional source with narrow spectral linewidth, which make it important, particularly in communications (Sargent, 2008). There are many types of lasers, each type has its own properties and applications, for example the selection of gases in gas lasers which depends on the coincidence of the absorption lines and the lasers line (Uotila, 2007). For example, free electron lasers FELs are high power sources of electron radiation (Kimmitt et al, 1996), such sources are brighter than synchrotron; furthermore IR beams produced by these lasers are different from those produced by the synchrotron; because lasers beams are monochromatic but the synchrotron beams are very broadband; because of the pulse time which is more in synchrotron (Smith, 2002). Other types of IR lasers are InAs and GaAs lasers of equal flat p-n junctions; their cavities are unequal as the defects of planeity of InAs are smaller than they are in GaAs (Rodot et al, 1966), and the InAsSb-based lasers which produce mid-infrared with an emission range of 3.8 to 3.9 μm, such lasers can be operated up to 210K (Allerman et al, 1996). Smith-Purcell types of FELs called Orotrons or Ledatrons and Cerenkov lasers, works at long wavelengths from 100 μm to 3mm, on the U.K FEL there was a spontaneous output in the visible and near IR (Kimmitt et al, 1996). The CO_2 laser is a near IR gas laser capable of very high power and with an efficiency of about 20 percent (Hollas, 1997). Lead- salt lasers having emission wavelengths larger than 3μm had low output power; as they have low thermal conductivity; such lasers are operating in single mode (Aidaraliev et al, 1996). Laser diodes are another example of IR sources (Bogue, 2003). It was found that obtaining laser action using Compton scattering is possible to generate IR radiation (Sukhatme et al, 1974).

2.3.5. Pulsed wideband infrared thermal sources:

Another type of IR sources is the pulsed mid-IR thermal source which is based on electrical heating of a thin metal alloy foil followed by self cooling process, examples of these alloy foils are Fecralloy and Hastelloy. The simple process of manufacturing a thin film; make it easy for these types to spread widely and got a considerable attention. These sources are treated as a black body radiator, with thermal emissivity ε=1 and associated change in emitted power depending on Stefan-Boltzmann law $W=\sigma T^4$:

$$\delta P = 8S\varepsilon\sigma T^3\delta T \quad (2.9)$$

Where S is the area of a single side of a foil, σ is a constant ($\sigma=5.67\times10^{-8}Jm^{-2}K^{-4}s^{-1}$) and the power change per cycle required to raise the foil's temperature by δT is:

$$\delta P = c_p\rho dS\delta T / \, pulse\ \ duration \quad (2.10)$$

Where c_p is the specific heat of the material, ρ is the metal foil density and d is the foil's thickness.

From equations 2.9 and 2.10; the frequency of thermal pulses can be expressed as: (Lainé et al, 1997):

$$f = 8\varepsilon\sigma T^3 / c_p\rho d \quad (2.11)$$

In these metal sources the geometry and the type of foil is important, foils of low $c_p\rho$ are used to protect foils from high values of heater current, thermal expansion coefficient must be low so that physical distortions and strains during repetition of heating are minimized. Fecralloy foils consist of Fe (72.6%), Cr (22%), Al (4.8%), Si (0.3%) and Y (0.3%). Such sources are operating to a maximum temperature in air from 1100 to 1300°C. The resistivity of Fecralloy is 134 μΩcm and thermal conductivity of 11.5 $Wm^{-1}K^{-1}$ (Lainé et al, 1997).

2.3.6. Other infrared sources:

Infrared sources are nicely and easily found; the short intense electron source is an example of a new generation source of far-infrared; when the electron beam pass through a thin Aluminum foil, transition far infrared radiation is formed in the form of a Fourier transform limited radiation pulse. The coherent far infrared radiation has energy of approximately 100nJ per micropulse this exceeds that of most blackbody or synchrotron radiation source (Woods et al, 2004).

The so called Canadian light source CLS is an infrared source used for spectroscopy and constructed of two beam lines; the first provided a mid infrared (2-25μm) radiation, and the other one in the far infrared (beyond 25μm) and used for gas-phase and surface spectroscopy (May, 2004).

2.4 IR detectors

The most helpful devices which can help in understanding waves are detectors, as our eyes are the detectors of visible light. Even though, IR detectors are required in detection of human being presence such as motion and angular velocity, to do this simply; array of sensors which covered with resist having absorption bands corresponds to the IR radiation emitted by human beings are required (Freitag et al, 1989). Interests in applications such as military applications of IR radiation; led to the development of improved IR detectors (Jones, 1961).

For IR to be detected correctly; the detector material must be selected according to the wavelength of the optical signal (Rodot et al, 1966), in general, infrared detectors can be

classified into two categories: photon detectors which have high signal to noise ratio, very fast response and a cryogenic heavy expensive cooling system requirement, the other type is thermal detectors operating at room temperature so the power consumption is decreased (Chi-Anh et al, 2005).
In thermo-electrical infrared detectors; the change of the temperature of the detector element, as the result of absorption or emission of radiation will be translated as a signal (Anderson, 1961) such detectors need no cooling, with sufficient detectivity and resposivity for many applications; they are also inexpensive detectors (Tank et al, 1991). As detector is the heart of an IR system; it's difficult to choose the suitable detector, especially when cooled detectors are used (Anderson, 1961).

Generally; for both bolometer and photo conductors detectors which use the electrical conductivity of the detector element to sense the radiation, which is a function of temperature for bolometer, but the photo conductivity is not (LA Roche, 1973).

2.4.1. Theory of detectors:

In defining the physics of detector devices; several terms deserve explanation. One of these is the noise equivalent power (NEP) in $W/Hz^{1/2}$ which is a measure of the performance of detectors and defined as:

$$NEP = \frac{V_n}{R_v} \tag{2.12}$$

Where V_n (v/Hz$^{1/2}$) is the rms (root mean square) detector noise voltage, and R_v (v/W) is the detector voltage responsivity (Smith, 2002).

Another essential term is specific detectivity D* which is defined as the detectivity of a radiation detector as a function of the square root of the product of the active detector element area (A) and the band width (W, in cycles per second), divided by the noise equivalent power (NEP, in Watts) of the detector element and given by:

$$D^* = \sqrt{A \times W}/NEP \tag{2.13}$$

Where the D* is in units of cmHz^{½}W^{-1} (La Roche, 1973). D* is a considerable and widely used parameter particularly in infrared technology to contrast devices with dissimilar areas (Sargent, 2008).

Another parameter rather than detectivity is the responsivity R which is the amount of output signal per unit of input radiant power (Chi-Anh et al, 2005) and the time constant which are important; especially for thermo electrical detectors. The thermal time constant τ_{th} of the detector can generally be given by:

$$\tau_{th} = R_{th}C_{th} = R_{th}\rho c V \tag{2.14}$$

Where R_{th} is the inverse heat conductivity (K/W), C_{th} is the heat capacity (J/K), ρ is density of the detector material (kg/m^3), c is the specific heat (J/kgK) and V is the detector volume. In defining R_{th} and according to Stefan Boltzmann law it's given by:

$$R_{th} = \frac{\Delta T}{4F_D\sigma_o(T^4 - T_D^4)} \approx \frac{1}{4\sigma_o T_D^3 F_D} \tag{2.15}$$

Where T_D is the detector temperature (K) without irradiation by the black body; T is the detector temperature (K) with irradiation by the black body; ΔT is the increase of the detector temperature caused by the irradiation. F_D is the area of the detector surface; σ_o is the Stefan-Boltzmann constant (Tank et al, 1991).
The response of the detector is governed by the following equation:

$$R_s = \frac{R_{so}}{(1+(2\pi f\tau)^2)^{1/2}} \tag{2.16}$$

where R_{so} is the responsivity at zero frequency, f is the frequency and τ is the response time (Kimmitt et al, 1996).

The power in which will reach the detector from a light source is very important term to be known and can be expressed as:

$$SP(\lambda) = B(\lambda)\theta\xi\Delta\upsilon \quad (2.17)$$

With $B(\lambda)$ is the source brightness, θ is the instrumental (experimental) throughout or acceptance (or etendue), $\Delta\upsilon$ is the resolution bandwidth and ξ is the optical efficiency (Smith, 2002).

2.4.2. Types of IR detectors:

Usually, IR radiation (with wavelength λ>800nm) can be detected either photographically or using a heat detector (Kemp, 1987). IR detectors are widely spread; from those is the high sensitive infrared photo-detectors which are appropriate to image sensor technology; these detectors are manufactured using simple solution processing, recently, they have the greatest performance (Sargent, 2008).

There are three classes of uncooled thermal detectors: bolometer, ferroelectric and thermopiles (Foote et al, 1998), ferroelectric detectors produced unsurpassed image quality. On the other hand, Micro-bolometer technology products are smaller. A new array of ferroelectric detectors have been fabricated with no need to temperature stabilization with a calibration of single room temperature as they can be used from -40˚C to 85˚C (Hanson et al, 2008).

Thermal detectors such as thermopiles respond uniformly to all IR wavelengths, but they are less sensitive than quantum detectors over limited wavebands. Thermopiles are the most inexpensive and favored thermo electrical detectors when lower performance is acceptable (Dann, 1994), this type of detectors is used in most modern instruments (Kemp, 1987), they can be operated producing output voltage without bias or chopping. And have high linearity larger of magnitude than the incident infrared power (Foote et al, 1998), thermopiles were made of evaporated elements of Bismuth and Antimony on Collodion film, but were not sensitive. Bolometer is another type of IR detectors (Jones, 1961) which made of a self-absorbing platinum-film array, this type of detectors consists of three-layer stack compressing a perfectly reflecting metal film, with a layer of quarter-wave dielectric and a resistance of the form of metal film sheet, with these components the thermal capacity will increase significantly and so increase the response of the detector. The dielectric material component of this detector is such that of the thin film pyroelectric or dielectric bolometer or the semiconductor layer in a semiconductor film bolometer (SFB) IR detector (Liddiard, 1993), in order to eliminate the effects of the background and to show up the point source; a several schemes were outlined depending on the use of fast thermo elements or bolometer. Adjacent thermo-elements connected to the input transformer of an AC amplifier (Jones, 1961). Cd-doped Ge is an example on bolometers which operates at 0.3K, it's a very sensitive detector for low levels, and it has also a flat response over a wide range of photon energies. This detector is often the preferred detector in infrared astronomy (Brown et al, 1995).

Thermopiles and bolometers detectors depend on the thermocouple principle which states that if two different types of metal wires are connected head to tail, then a difference in temperature between head and tail causes a current to flow in the wires, and this current

will be proportional to the intensity of radiation falling on the detector material (Martin, 1980). The two types were developed in the Clarendon laboratory at Oxford and used to examine the IR spectrum of the sun (Jones, 1961)
The Golay cell was the most common detector used in the early days. Its high sensitivity nearly over all of the useful spectral range is an advantage; however it has a slow response with an optimum chopping frequency in the region of 10 Hz and can be somewhat temperamental. Triglycine sulphate (TGS) is the type of detector which has a gas chamber and a parallel planer capacitor in the form of a silicon layer, incident infrared heats the gas resulting a deflection of the silicon layer detected as a capacitance change of the capacitor (Yamashita, 1999).

The Putly InSb detector is another detector which can be used at very low frequencies (<10 cm^{-1}) with high sensitivity (Martin, 1980). Indium antimonide (InSb) multichannel imaging detector is used for infrared absorption micro-spectroscopic (Treado et al, 1994), and considered to be the most popular 1-5μm detector in astronomical applications because of its low noise, its current pass through a feedback resistor, then an AC- coupled mode by a lock-in amplifier is used to measure the resulting voltage. It's found that 60% of incident photons are converted to electrons that is the quantum efficiency of InSb is 0.6 (Barton et al, 1980).

Photoconductor detectors are of a straight forward detection Mechanism for both intrinsic and extrinsic semiconductors, the free electrons and holes in intrinsic produced by the effective energy photons as the result of valence conductors and conduction band of a semiconductor. On the other hand, free electrons produced as the result of transitions from donor impurity states to the conduction band in the extrinsic photoconductors, or holes created as the result of transitions from the valence band into acceptor states. The two processes occur either in intrinsic or extrinsic will reduce the resistance of the semiconductor resulting of a passage of current through the detector (Kimmitt,1991) briefly incident radiation on the photoconductive detectors produces a change in the electrons distribution or a change in carrier population; this will change the conductivity (Gornik et al, 1994). Such detectors like indium antimonide must be cooled for better performance for wavelengths longer than a few microns. ; However; it was found that it's possible to get uncooled solid state detectors using band semiconductor heterostructures (Ashley et al, 1996).

Generally, intrinsic materials such as HgTeCdTe solid solutions are of great interest and with this material a wide range of devices can be realized (Rodot et al, 1966) but, it was found that intrinsic detectors are faster and works at higher temperatures than impurity photoconductors, and because of the small energy gap of semiconductor (like InAs and InSb) one can build IR fast detectors in a wide wavelength range (3 to 15 microns) taking into account also that intrinsic detectors have short time response, Although InSb detectors can be considered as fast responsive to sources (Rodot et al, 1966) however; Extrinsic germanium photoconductors are preferred below 200 μm (Kimmitt et al, 1996).

Photovoltaic or photodiodes detectors are types of detectors in which the energy gap is less or equal to the photon energy, the used p-n junction or the metal-semiconductor junction (schottky barrier) will create a built-in field that makes the device as a current or voltage generator by the separation of electrons and holes. The avalanche photodiode is a good example of alternate photovoltaic detectors; on the other hand InGaAs, InAs, InSb or HgCdTe can be used to make photovoltaic detectors to cover the 1-20 μm regions at 77 K.

Conductivity of photoconductors with resistance R is proportional to the number of the excited electrons (n) such that:

$$n = N_0 + \delta n(t) \tag{2.18}$$

And

$$R = \frac{K}{n} = \frac{K}{N_0 + \delta n(t)} \tag{2.19}$$

K is a constant of proportionality. N_0 is the equilibrium number of excited electrons in the absence of the incident light signal. And $\delta n(t)$is the increase in the number of excited electrons due to the incident light signal (Penchina et al, 1966).

In the photo electromagnetic detectors the electron hole pairs are created near the surface of semiconductors as the result of the incidence of photons having grater energies than the energy gap. A photo voltage is produced as the result of a perpendicular applied magnetic field to the direction of the electrons and holes that diffuse through the bulk of the material. HgCdTe photoelectromagnetic detectors operate at room temperature and the response wavelength is 12 μm (Kimmitt, 1991). For the general formula of Mercury cadmium telluride detector (Hg_{1-x} Cd_x Te with x≈0.2); it is used for detection of infrared radiation up to a wavelength of over 20 μm (He et al, 1995), The detector has a fast response and the spectral range depends on the exact value of x and other factors; the region 400 to 5000 cm^{-1} can be effectively covered (Martin, 1980), this detector needs cooling either by liquid nitrogen, or by closed-cycle refrigeration (Bogue, 2003).

Generally, thermal detectors are not sufficient in FELs; pyroelectric detector is an exception as it can be used as a very fast detector in which thermal radiation can be detected as a change of charge of the capacitor (Kimmitt et al, 1996).

Pyroelectric detector is better than the Golay at frequencies above 50 Hz. This detector can be used at high chopping frequencies (>1000Hz with loss of sensitivity) and is usable from 2 to > 300μm (Martin, 1980). To make a good pyroelectric detector; its pyroelectric coefficient (rate of change of charge with temperature) must be high, and with small thermal mass and low dielectric constant (Kimmitt et al, 1996). In these detectors also changes in temperature initiate changes of the charge of the capacitor plates which can be detected as voltage changes in an open circuit (Tank et al, 1991). They are not thermoelectric detectors such as thermocouples but they are high-frequency thermal detectors. The maximum response is observed at a time shorter than the thermal relaxation time. These detectors consist of a thin wafer of suitably poled and oriented dielectric crystal which acts as a charge generating capacitor. It's easy to use these detectors in applications as they require no cooling and consume very little power. A pyroelectric material produces current as it experiences a change in temperature. If a change in temperature produce a polarization dP_s in time dt then the pyroelectric current/ unit area of the crystal is:

$$I_{py} = \left[\frac{dP_s}{dT}\right]\left[\frac{dT}{dt}\right] \tag{2.20}$$

Where T is the temperature, P_s polarization/volume, t is the time, dP_s/dT is the pyroelectric coefficient and denoted by P, and dT/dt is the rate of change of T (Hossain et al, 1991).
The pyrocurrent of pyroelectric detectors can be expressed as:

$$i_p = \tau_F . \alpha . \phi_S . \frac{p}{c'_p . d_p} . T_R = pyro \quad current \tag{2.21}$$

Where: τ_F is the window transmission, α is the absorption capability of chip, ϕ_S is the incident radiant flux, p is the pyro coefficient, c'_p is the volume-specific heat capacity, d_p is the thickness of the chip and TR is the normalized current sensitivity. It's clear that the pyrocurrent is proportional to ϕ_S and independent of chip size for uniform illumination (Internet: http:/lasercomponents.co.uk, 2009) this type of detectors is used in IR absorption spectroscopy and required a modulated (switch on and off) incident power this can be achieved by using an electrically pulsed low thermal time constant blackbody source or by using a continuous blackbody source with a mechanical chopper, the last method has disadvantages of the moving parts and need to be performed in high acceleration environment. Pulsed sources are restricted to low chopping frequency this limits the time response and introduce 1/f noise (Fairley et al, 2001). Such detectors can detect infrared radiation from a heat source at room temperature with a sensing range of 8 to 14μm; its detectivity depends on the frequency of the chopper, the highest detectivity of a pyroelectric detector is highest when the chopping frequency is 1Hz (Lee et al, 2007).

Rectifying detectors are a millimeter and longer wavelengths fast detectors over a reasonable power range. These detectors obey the square law, which is the voltage should be directly proportional to the input power, taking into account that laser power or electromagnetic interface can easily destroy the diodes (Kimmitt et al, 1996).
Optical transform image modulation OTIM is an open-ended gas detector which was built in 1988 to detect Sodium line in the exhaust plumes, in these days it is called Gas Cam (Bogue, 2003).

The main noise sources of such detectors are: the temperature fluctuation's noise which comes from the fluctuations in the power flow and lateral heat conduction in the substrate or in the pyroelectric thin film, the Johnson noise, the amplifier current and voltage noise (Liu et al, 1994).

2.5 IR spectroscopy

Spectroscopy is an experimental subject which takes care of the absorption, emission or scattering of electromagnetic radiation by atoms or molecules (Hollas, 1997) as the incident radiation are with different IR frequencies; Some of the frequencies of the IR light passed through a sample (as an organic compound) are absorbed while other frequencies are transmitted through the sample without being absorbed. Plotting percent absorbance or percent transmittance against frequency will give a result which is the IR spectrum (Kemp, 1987) to transform given data from a source; a signal is taken from detector through a processing system that converts it to spectral form (Bogue, 2003). Briefly; one can say that in the photo thermal characterization detection method which is called IR radiometry the following occurs: heating of the sample using optical methods, thermal transport in the sample and detection of the temperature of the surface by certain methods such as measuring the intensity of the emitted infrared radiation (Osiander et al, 1998). It was found that the most appropriate method of the heat flux excitation which can be applied with infrared detection is induction heating (Suszyn´ski et al, 2004). Generally, a more frequently techniques used in all regions of the spectrum is the absorption spectroscopy (Hollas, 1997).

Inside the IR radiation exposed material; certain changes will occur such as vibrational and rotational movements of the molecule (Kemp, 1987). Transitions between rotational energy levels associated with the same vibrational levels will be observed in rotational spectroscopy. On the other hand; transitions between many rotational energy levels associated with two different vibrational levels will be observed in vibration-rotation spectroscopy. These transitions accompany all vibrational transitions but, vibrational transitions may be observed even when the sample is in the liquid or solid phase, however in the gas phase at low pressure only rotational transitions may be observed as an absorption process (Hollas, 1997). On the other hand, the vibration-rotation spectral bands of polar molecules can be considered as the mechanisms of absorption (Smith et al, 1997).

IR spectrum is a good method to know the components of a mixture (Kemp, 1987) or even to distinguish different materials such as glasses, different plastics and other transparent solid. Beside that the concentrations of specific liquid and gases also can be measured by using IR absorption (Bryant et al, 1992). In dealing with samples; it is found that Sample preparation method, optical interface between the sample and the IR instrument –sampling accessory- affects the quality of IR spectrum. Different sampling accessories which use different principles of optical measurement produce variations in the appearance of the final spectrum for the same sample and this must be taken into account to get accurate results in IR spectroscopy (Workman, 1988).

Treating samples with IR can be achieved by many techniques depending on whether the sample is a gas, a liquid or a solid, as intermolecular forces vary considerably in passing from solid to liquid to gas (Kemp, 1987) and (Workman, 1988) That is the types and number of the present absorbing molecules determined by the amount of the optical radiation passing through a substance and this will give an indication about the concentration and thickness of the absorbing material (Bryant et al, 1992), which means that IR spectrum depends on the phase of the sample for example: under high resolution gas-phase IR bands consists of closely spaced lines- the rotational fine structure, however; IR bands of liquids and solids very rarely show rotational fine structure (Hollas, 1997) as molecules in most solids are held in fixed lattice positions and are not free to rotate, but, In liquids; the high rate of intermolecular collisions and the substantial intermolecular interaction cause random shifts in the rotational energies, thereby broadening the rotational lines of a band sufficiently to merge them into one another, and eliminate the rotational fine structure (broadening of fine structure lines is also observed in gas-phase spectra when the pressure is increased (Levine, 1975); so one has to take care and time at the moment of sample preparation, choose the suitable technique and understand the difference between measurement techniques, this will save time and effort (Workman, 1988). For example, recently; mid infrared radiation (MIR) has not been used to quantify multiple components in aqueous solutions; one reason for that is very pronounced water absorption (Roychoudhury et al, 2006).

Beer-Lambert law describes the un-attenuated radiation intensity and given by:

$$I = I_o e^{-\alpha l} \tag{2.22}$$

Where I is the un-attenuated radiation intensity, I_o is the intensity before absorption, l is the path length and α is the absorption coefficient at a particular wavelength. Explains the IR gas detection based on absorption (Bogue, 2003).

The absorption can be expressed as: $[I_o - I]/I$ and the transmittance is the fraction: I/I_o the absorbance given as a function of the wave number ν is called the infrared absorption spectrum and expressed as:

$$-\ln\left[\frac{I(\nu)}{I_o(\nu)}\right] = \beta(\nu)cd \tag{2.23}$$

Where; β(ν) is the absorptivity, c is the concentration and d is the thickness of the sample (Kauppinen et al, 2003).

Foretelling of energy gains and losses to and from structures is important process to understand conservation and control of energy. IR reflectance and transmittance from any surface is used to quantify energy transfer. The spectral emissivity$\epsilon(\lambda)$ is given by:

$$\epsilon(\lambda) = 1 - [\rho_d(\lambda) + \rho_r(\lambda) + \tau_d(\lambda) + \tau_r(\lambda)] \qquad (2.24)$$

Where: λ is the wavelength, $\tau_d(\lambda)$ and $\tau_r(\lambda)$ are diffuse and regular components of transmittance, $\rho_r(\lambda)$ is the regular reflectance, $\rho_d(\lambda)$ is the diffuse reflectance. The total emissivity is given by:

$$\epsilon_T = \int_0^\infty \epsilon(\lambda)\lambda^{-5}[\exp\left(\frac{c_2}{\lambda T}\right) - 1]^{-1} d\lambda / \int_0^\infty \lambda^{-5}[\exp\left(\frac{c_2}{\lambda T}\right) - 1]^{-1} d\lambda \qquad (2.25)$$

Where c_2 is Planck's second radiation constant, It's difficult to measure the absolute reflectance of a surface over the mid –to far-IR spectrum (Clark et al, 1985).

Emission measurements may be performed, but with less frequent for analytical chemistry applications. Measurements usually used through light transmission passing through the sample or by reflection directly from the sample surface or from an interface. Absorption cross section of molecules in the mid-IR can be extremely high; this will determine which method should be used for recording the spectrum (Workman, 1988).

IR spectroscopy can be generally performed measurements in at least three spectral regions: near-IR, mid IR and far IR. Commonly, when the term IR is applied, this implies the mid IR spectral region, defined by the frequency range 4000-400cm^{-1} (2.5-25 μm in units of wavelengths), this range is arbitrary defined, but the upper spectral limit defines the extent of all the fundamental molecular vibrations, with the exception of that of hydrogen fluoride. The lower limit is normally defined by the optics of the instrument (Workman, 1988).

When infrared radiation flux is incident on a surface such as semi-transparent body; it will partly reflected in specified directions. And partly reflected in all directions and partly refracted through a rough semiconductor wafer surface. To avoid polarization and interference phenomena; an extended non-monochromatic radiation source and a normal incident beam can be applied. Phenomena outside the limit of main absorption affect the transmission in the infrared region such as: free carrier absorption, multiphonon absorption, lattice scattering, doping, defects and precipitates (Piotrowski et al, 2000).

Prior 1940 applications of IR spectroscopy were limited to research in molecular structure using spectrometers formed by research workers which were difficult to use; because the IR spectrum had to be measured, plotted point by point, and the spectrometers were very sensitive to disturbances such as fluctuations in room temperature. Recently, the resulting simplicity and rapidly of IR spectroscopy operation made it a standard tool in research and industrial work (Levine, 1975).

Now days, IR spectroscopy becomes a simple process and have many applications possibilities as applications in pharmacy. Cheapness, simplicity and the short time to record the spectrum are a positive side of the method (Kalinkova, 1998).

On the other hand, in the field of gases; absorption spectroscopy is used to determine the concentration and types in a gas sample; concentration of a known test gas can be determined by integrating the absorption over one of its absorption bands (Fairley et al, 2001), this technique is also used in detecting the range of polluting gases (Bogue, 2003). In medical applications; near-IR spectroscopy is used by medical researchers to study changes of oxygenated hemoglobin (HbO_2) concentration (Macnab et al, 1996). Also, infrared light sources are used to detect microorganisms in blood culture vials; by the determination of the absolute CO_2 concentration (Klaus).

In the field of infrared microspectroscopy; it was used with a synchrotron radiation source which is well- suited to this technique (Carr, 1998) for example, synchrotron was used to examine the photodimerisation of chloro-derivatives of trans-cinnamic acid by an in situ time-dependent study (Atkinson et al, 2003). Even in food industry analysis and constructive measurements of chemical compounds; infrared spectroscopy techniques are increasingly used. Since materials are subjected to heat; they will become hot acting as infrared sources, then the original source is removed and an emission spectrum is obtained (Kemsley et al, 1995).

Efficient laboratory applications are submitted also by near infrared spectroscopy. Petroleum industry is an example of near infrared useful applications especially in monitoring the quality of products (Balabin, 2007).

For each spectroscopy application; it is reasonable to choose the suitable source and detector, for example, in high-resolution spectroscopy and trace gas detection; mid infrared tunable diodes laser are a powerful single mode emission device with a high power, narrow linewidth and low intensity noise (Weidmann et al, 2000).

For higher spatial resolution spectroscopy, the synchrotron is used (Smith, 2002) because, synchrotron radiation is a high intensity source in the terahertz (THz) region with a diffraction limit resolution (Kimura et al, 2006), this source has an important quality in producing infrared radiation which is the high source brightness, which allows infrared microspectroscopy to be performed on sample regions having an equal size to the wavelength of light (Carr, 1998). On the other hand, it was found that using semiconductor lasers as a source of IR spectroscopy research increases the resolving power over traditional IR grating spectrometers. As the laser line width is $1/100^{th}$ the width of the Doppler-broadened absorption lines of the gases, thus fine details of IR line shapes is easily obtained. Polyatomic molecule IR spectrum consists of series of bands so rotational fine structure under high resolution is obtained (Levine, 1975), for pulsed lasers; the photoacoustic detection can be used; because of their wider IR tunability and because they give better spectral overlap with molecular gases (Harren et al, 2000). Laser radiation is very much more intense than that from the source, for example, mercury arc; so conventional Raman experiments with laser sources can be carried out. Other than Raman spectroscopy most laser sources may have disadvantages that of non-tunability (Hollas, 1997).

The Fourier transformed IR (FTIR) spectroscopy can be used in different applications such as photoacoustic; because IR light sources combined with photoacoustic detection schemes are commercially available for trace gas detection (Harren et al, 2000) also, for the use of studying the adsorption of water; far infrared spectroscopy has been used, to do so the spectra were recorded on a Fourier Transform Interferometer (Smart et al, 1975). Measuring concentrations of components in complex mixtures is another technique in which Fourier transformer spectroscopy is used. Using this technique will produce a fingerprint to molecules forming chemical bonds by producing an infrared absorption spectrum (Roychoudhury et al, 2006). Usually in the technique of Fourier transform Raman, or FT-Raman, spectroscopy IR laser is most often used which is Nd-YAG laser operating at a wavelength of 1064 nm (Hollas, 1997).

However; in using IR absorption measurements by LED one can measure the water content of insulating oil spectroscopy (moisture-in-oil monitoring); another example of this method is gas monitoring (Bryant et al, 1992) this method can be considered as the most rapidly developing of all as sensing techniques (Bogue, 2003).
Infrared is important in photoacoustics as it is absorbed by the molecules of the gas inside the photoacoustic cell. Common infrared sources used are lasers such as diode lasers, quantum cascade lasers and gas lasers; another source is the ceramic blackbody radiators (Uotila, 2007). Otherwise, sources such as infrared thermocouples are often used in agricultural research; however the high cost of them has limited their use in production agriculture settings (Mahanb et al, 2008).

The spectral radiant intensity S at frequency ν is related to the position X within a sample by the general radiative transfer equation in which the radiative emission and absorption processes are described, the relation can be expressed as follows:

$$\frac{dS}{dX} = [N_2A - \left[(N_1 - N_2)BS\frac{4\pi}{c}\right]]\frac{h\nu\phi(\nu)}{4\pi} \qquad (2.26)$$

With; A and B are the Einstein coefficients and related to each other as:

$$A = 8\pi h\left(\frac{v}{c}\right)^3 B \qquad (2.27)$$

A determines the rate of the spontaneous emission process and B the rate of stimulated emission and absorption processes. N_1 and $N2$ are the volume population densities of the ground and exited states respectively. $\phi(\nu)$ is the line-shape function for the transition, c is the speed of light in vacuum and h is the Planks constant. At equilibrium; N_1 and N_2 are related by the Maxwell-Boltzmann distribution as:

$$N_1 = N_2\exp\left(\frac{h\nu}{kT}\right) \qquad (2.28)$$

and

$$N_1+N_2=N \qquad (2.29)$$

With N is the total oscillator volume density. Where k is the Boltzmann constant and T is the temperature of the sample (Kemsley et al, 1995).

2.5.1. Reflection of infrared radiation:

An incident photon beam of electromagnetic radiation on the surface of an object can be absorbed, reflected or transmitted. The IR diffusely reflected radiation is due to the incident radiation on the surface from an infrared radiation source and obeys Lambert's cosine law: (intensity is proportional to the cosine of the angle between the incident radiation direction and the normal to the surface):

$$I_d = k_d I_l cos\theta \qquad (0 \leq \theta \leq \pi/2 \qquad (2.30)$$

Where I_d and I_l are the infrared diffusely reflected intensity and incident intensity from a point radiation source, k_d is the infrared diffuse reflection constant and θ is the angle between the incident radiation direction and the surface normal. Taking into account the ambient components the infrared reflected radiation intensity can be expressed as:

$$I = k_a I_a + I_l k_d cos\theta \qquad (2.31)$$

I_a and k_a are the infrared incident ambient radiation intensity and infrared ambient reflection constant (Wang et al, 2003).

For an emitter of radiant power R_i, and half beam angle ϕ; placed a distance d far away from a detector of active area S; the steradian Ω can be calculated by: S/d^2 when the emitter is facing the detector directly, with an angle θ between the normal of the detector surface and the incident ray, the steradian can be expressed as:

$$\Omega = \frac{S\cos(\theta)}{d^2} = SL/d^3 \qquad (2.32)$$

With L is the horizontal separation between the emitter and the detector. Using Phong's reflected power model; the collected optical power is:

$$R_{los} = R(\theta_i, \theta_o)\Omega \qquad (2.33)$$

$$= \rho\frac{R_i}{\pi}\{r_d\cos(\theta_o) + (1 - r_d)cos^m(\theta_o - \theta_i)\}\Omega$$

$$= \rho\frac{R_i}{\pi}\{r_d\cos(\theta_o) + (1 - r_d)cos^m(\theta_o - \theta_i)\}SL/d^3 \qquad (2.33')$$

Where θ_i and θ_o are the incident and observation angles respectively, R_i is the incident optical power and r_d is the percentage of incident signal that is reflected diffusely and assumes values between 0 to 1, m is a parameter which controls the directivity of the specular component of the reflection and ρ is the power conversion coefficient. As the emitter has a limited emitting angle ϕ; the power incident on the detector active surface can be written as:

$$R_{los} = \beta(\phi)\rho\frac{R_i}{\pi}\{r_d\cos(\theta_o) + (1 - r_d)cos^m(\theta_o - \theta_i)\}SL/d^3 \qquad (2.34)$$

As ϕ is a limited emitting angle of the emitter; β(ϕ) can be expressed as a step function as:

$$\beta(\phi) = \begin{cases} 1 & if\ \phi \leq emitting\ angle \\ 0 & if\ \phi > emitting\ angle \end{cases} \qquad (2.35)$$

Each reflecting surface element, ΔA_{xy} can be assumed as a secondary source emitting from the central point of the surface with reflection coefficient $\rho_{\Delta A}$. Then the incident power on an element of a reflecting surface is:

$$R_{\Delta A} = \oint_{\Delta A}\rho_{\Delta A}\frac{R_{\Delta A}}{\pi}\{r_d\cos(\theta_o) + (1 - r_d)cos^m(\theta_o - \theta_i)\}\cos(\gamma)\,L/d^3dA \qquad (2.36)$$

With: γ is the angle between the direction of the ray and the normal of the surface element (Yang, 2000).

2.5.2. Wave guides:

A wave guide is a physical structure with different shapes boundaries of great importance in electromagnetic radiation especially at high frequency i.e. at wavelengths of orders of meters or less.

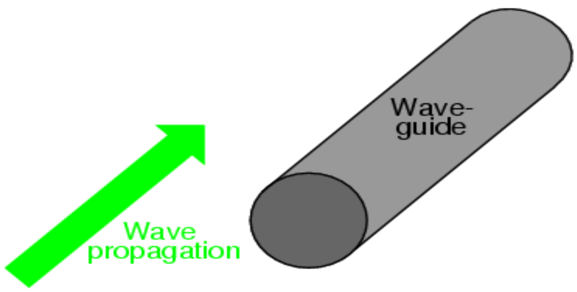


Fig. 2.3: Cylindrical wave guide.

Since the only practical way to generate and transmit electromagnetic radiation through metallic structures having comparable dimensions to the wavelengths involved. Hollow cylindrical wave guides are practical situations of considerable importance. For perfect conductors boundary surfaces and constant cross sectional area along the cylindrical Maxwell equations are:

$$\nabla \times \boldsymbol{E} = \frac{i\omega \boldsymbol{B}}{c} \tag{2.37}$$

$$\nabla . \boldsymbol{B} = 0 \tag{2.38}$$

$$\nabla \times \boldsymbol{B} = -i\mu\epsilon \frac{\omega}{c} \boldsymbol{E} \tag{2.39}$$

$$\nabla . \boldsymbol{E} = 0 \tag{2.40}$$

It is considered that the cylindrical filled with a uniform nondissipative medium having dielectric constant ϵ and permeability μ.

For a given frequency ω we have:

$$(\nabla^2 + \mu\epsilon \frac{\omega^2}{c^2}) \begin{Bmatrix} \boldsymbol{E} \\ \boldsymbol{B} \end{Bmatrix} = 0 \tag{2.41}$$

The wave number k is determined for each value of λ as:

$$k_\lambda = \left[\frac{1}{c}\right] \sqrt{\mu\epsilon} \sqrt{\omega^2 - \omega_\lambda^2} \tag{2.42}$$

With λ=1, 2, 3,………….. and ω_λ is the cut off frequency.

For ω>ω_λ, the wave number k_λ is real; waves of the λ mode can propagate in the guide (Jackson, 1962)

2.6 Conclusion

It is clear that IR radiation is produced by hot bodies and molecules, absorbed by most materials. The IR energy absorbed by a substance appears as heat because the energy agitates the atoms of the body, increasing their vibrational and rotational motion, which results in a temperature rise.

IR radiation has many practical and scientific applications, including physical therapy, IR photography, and vibrational spectroscopy.

Radiation source characteristics are important, IR portion of the spectrum is particular useful for identifying many chemical substances because their characteristic absorption spectra are distinctly different for this reason, IR spectroscopy is one of the most popular and powerful analytical techniques used by chemists for field measurements, a simplified version of the technique is employed to measure one or two specific substances.IR absorption is used widely to detect a range of hazardous and polluting gases.

Chapter three

Experimental system

3.1 Introduction

In this work; some of the miniature infrared sources such as Fecralloy foils and a Nichrome wire were built. Their shapes were designed and their characteristics were examined. A comparison of same width, different length and same length, different width sources was established. On the other hand; variant simple, no costly methods were improved to decrease beam divergence of emitted infrared radiation from miniature sources specially the two sided foils. These methods were compared so that to be used in focusing radiation and spontaneously increasing detected intensity. Miniature infrared sources can be used in widely range applications; this chapter will discuss some of these applications which are simple, useful and can be improved to be helpful in different fields of life. Applications which were applied are concerned with absorption of infrared radiation. It is better to place the source in a capsule to isolate it from the experimental environment.

3.2 Experimental design and set up

The experimental system was constructed from available simple devices. A Function generator, Low voltage AC/DC power supply of types TFG-462 and Pasco SF-9584A respectively were used in this work. To get pulsed sources; constructed sources were connected to a function generator which is used as a modulator. Function generator supplies small currents so the power supply is added to get the needed current to switch on the sources. A square wave was chosen to achieve self cooling process of the source. An IRF840 N - CHANNEL 500V - 0.75W - 8A - TO-220 PowerMESH^{TM} MOSFET was added to the circuit, this transistor was used as a switch to control high currents passing through sources. A Testmate 601 digital multi meter also was used as an ammeter. The most important part of this work is the detection of the infrared radiation, a P2613M silicon window of area=16.49mm^2 pyroelectric detector, gain adjust internal, serial number 277006 (scitec) was used. This small pyroelectric detector shown in Fig. (3.1) is very sensitive to heat so; it will do the job very well by connecting it to the Scitec 450S DSP lock-in amplifier which is indispensable device.

Fig. 3.1: A photograph of the pyroelectric detector used to detect emitted infrared radiation from miniature sources.

The lock in amplifier was used both as a filter and an amplifier, taking the function generator as a reference signal and comparing the frequency obtained by the detector, removing any external noise to get the best amplified signal. Using the Science workshop® 750 interface; the detected radiation will be translated to a voltage signal using the voltage sensor which is connected to the amplifier and the interface. On The data studio software; a graph of voltage versus time graph is plotted. The amplification value can be chosen from the software of the lock in amplifier. The source was fixed on a stand placed on an optical bench, facing the detector that was also initially fixed on a mobile graduated path 60mm far away from the source; and aligned in such that the window of the detector is placed coplanar to the center of the source.

3.3 Electronic circuits

3.3.1. Experimental set up circuit:

The set up below is the main experimental set up electronic circuit; it joins all devices together to power the IR source and simultaneously detect the IR radiation. The complete experimental set up is hence, shown in Fig. (3.2).

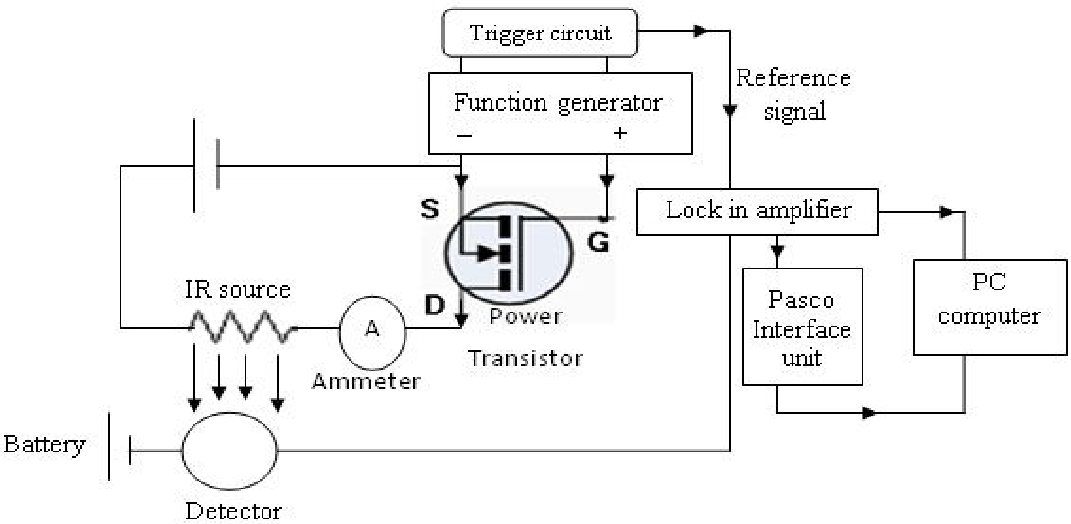


Fig.3.2: Schematic showing the complete experimental set up.

Figures (3.2 a) and (3.2 b) show photos of the general experimental set up and the set up used to study the intensity of IR radiation dependence on distance.

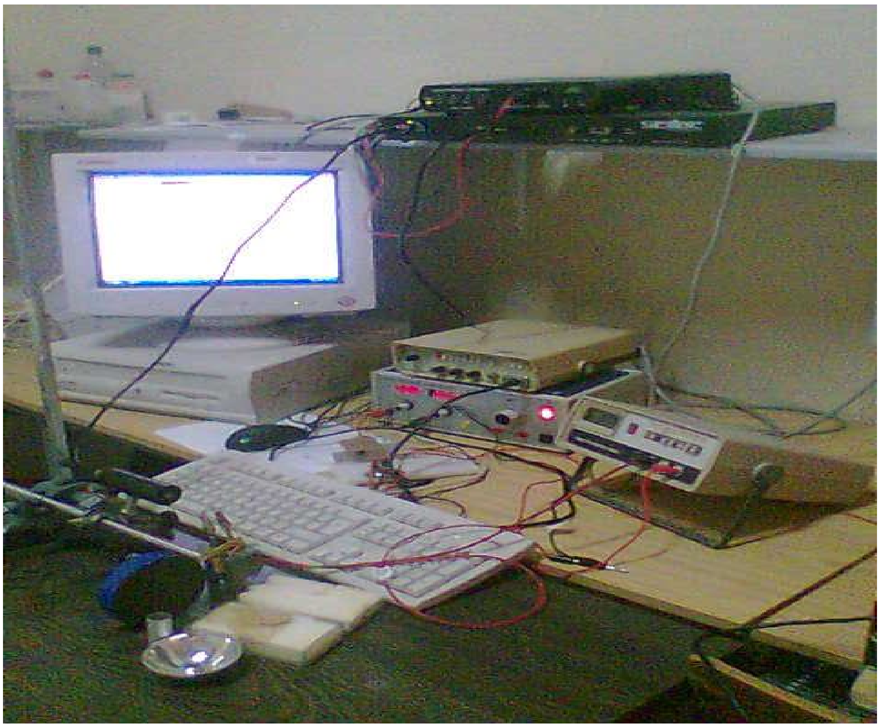


Fig. 3.2 a: A photo showing the experimental set up.

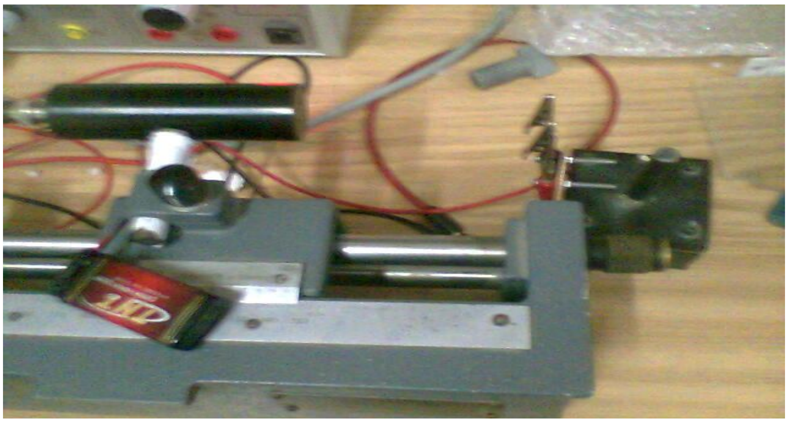
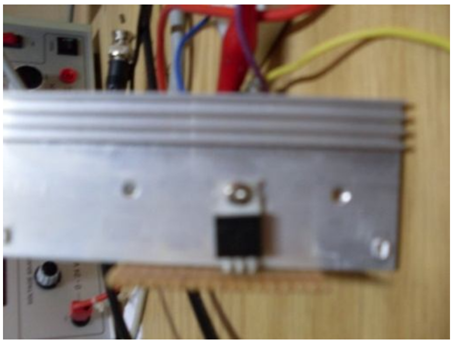


Fig. 3.2 b: A photo showing the experimental set up for studying intensity dependence on distance.

3.3.2. MOSFET transistor:

MOSFET is used for switching an analog input signal through a control circuit; the MOSFET has its gate connected at a gate junction and its source connected at a source junction. The control circuit further includes current source apparatus for generating a fixed enhancement voltage such that when the current source is applied the switching MOSFETs will be turned on and when the current source is disconnected the switching MOSFETs will be turned off.

Fig. (3.3) shows an IRF840 N - CHANNEL 500V - 0.75W - 8A - TO-220 PowerMESH™ MOSFET transistor that was used as a switch; its main purpose is to drive current from power supply to switch sources on because it has a high input resistance. As a closed switch; it's R_{DS} (resistance between source and drain) is very small so that current will pass easily. Its maximum gate threshold voltage (V_{GSth}) is 4V.



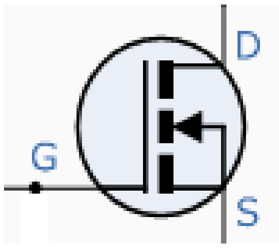


Fig.3.3: A sketch and a photograph of IRF840 N-CHANNEL MOSFET transistor

3.3.3. Trigger circuit:

An important Electronic simple circuit was added in order to limit the voltage across the lock in amplifier from the function generator which must be ~ 0.5V. This circuit is called the clipping circuit and consists of four carbonic resistors and two diodes connected as in Fig. (3.4) when the voltage from the function generator exceeds 0.7 V it will give us voltage of 0.7 V, with the load resistors this voltage is limited to 0.3V.

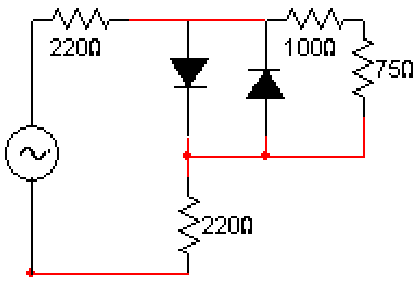


Fig.3.4: The clipping circuit used to trigger the lock in amplifier with 0.3 V reference signal.

3.4 IR sources design

Three different types of miniature IR sources were used; Fecralloy sources which were constructed from a Fecralloy sheet, a 2.5 V light bulb and a Nichrome wire constructed on the shape of a helix, the three types are discussed below:

3.4.1. Fecralloy sources:

Fecralloy is an alloy which consists mainly of iron and chromium; this heating resistance is excellent to oxidation at very high temperature (http://staging.goodfellowusa.com/fecralloy.htm, 2009). Fecralloy foils, consist of Fe

(72.6%), Cr (22%), Al (4.8%), Si (0.3%) and Y (0.3%), with a resistivity of 134 μΩcm and thermal conductivity of 11.5 $Wm^{-1} K^{-1}$ (Laine, 1997), other references consider it to be consist of Fe (72.8 %), Cr (22%), Al (5%), Y (0.1%) and Zr (0.1%) with a Curie temperature of 600˚C; their density is 7.22 g/cm^3 and the melting point is 1380-1490 ˚C (http://www.goodfellow.com/E/Fecralloy-Iron-Chromium.html, 2009).

Pulsed mid-IR thermal sources which are based on electrical heating of the thin metal alloy foil followed by self cooling process, are the main part of the experiment of the present study; in order to use them correctly to get the infrared radiation; they must be electrically heated to about 900-1000˚C (Laine, 1997) by a current passing through the source main element.

Different shapes and emitting areas were used. Sources of different lengths and widths were cut from a large size sheet material shown in Fig. (3.5)

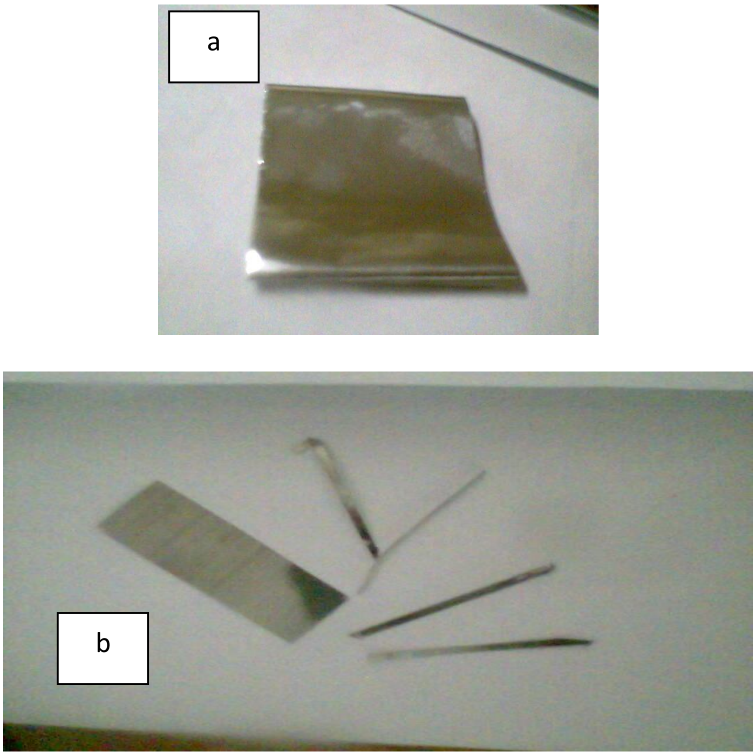


Fig. 3.5: a: A photo of the Fecralloy sheet used
b: The constructed sources from the Fecralloy sheet.

These foils, in general need a current, i.e. heated to emit infrared radiation. The amount of temperature to which are the sources supposed to be heated is dependent on the passing current. Accordingly, sheets were cut into the required size. The foil is usually attached to electrodes causing the current by spot welding. Spot welding technique using a high current supply is used, normally to achieve spot welding. Unfortunately; it was unsuccessful process for our case. Instead the trivial method was employed. The sheet foil was attached using two crocodiles, one of them is fixed on a plate and the other was mobile on a path done on the plate (i.e. it can be easily moved along this path to control sources length). The plate was fixed on a stand that was placed on an optical bench; so that the source was face to face on the same line of the detector and aligned in such a way that the window of the detector is placed coplanar to the center of the source. Current was increased until foil is dull red; at this situation infrared radiation is expected to be emitted. Three shapes of those sources were examined; there:

1) Rectangular foils with different lengths and widths. Description of this set of foils is given in table 3.1. below:

Table 3.1: Description of some rectangular foils used as IR sources.

Source	Length (mm)	Width (mm)	Resistance (Ω)
C	11	1.6	1.3
D	11	1.1	1.5
E	11	1.7	1.1
F	11	0.35	2.7
G	21	1.1	2.3
H	5	1.1	1.3

2) Bispiral source (K)
This shape of IR source shown (Keele university, 2006) in Fig.(3.6); has four legs passing through four equispaced 1mm diameter holes in a ceramic post with a diameter of 7.3mm and a length of 8.9mm.

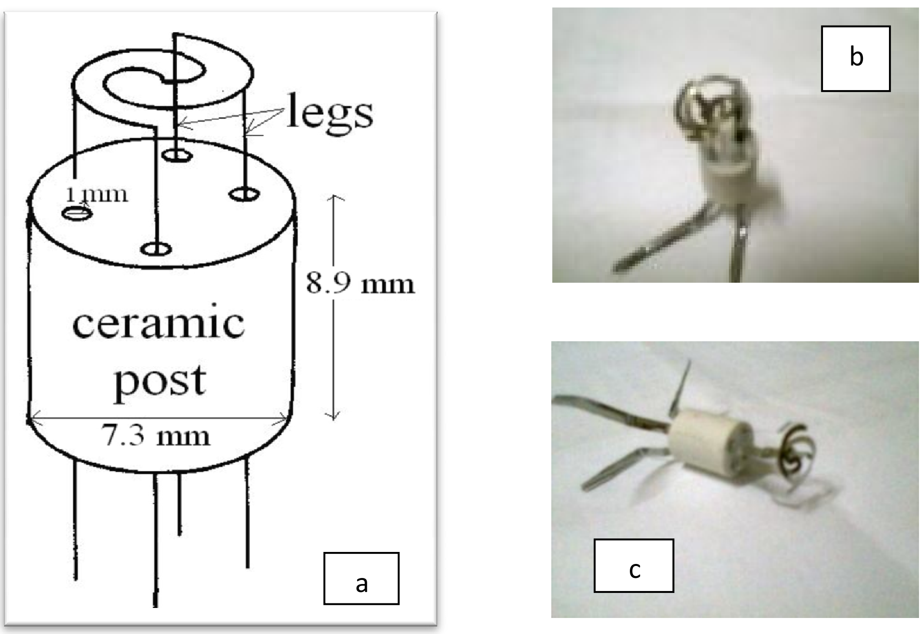


Fig. 3.6: a: Schematic showing the Bispiral IR source K (Keele university)
b and c: Photographs showing the Bispiral source K

3) Rhombic source (J)
This source has two legs passing through two equispaced 1mm diameter holes on a ceramic post with 7.3mm diameter and a 8.9mm long. The rhombic side lengths are not equal; their dimensions are shown in Fig. (3.7).

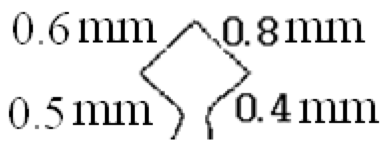


Fig. 3.7: Schematic showing the Rhombic source J.

3.4.2. Nichrome wire

A Nichrome wire consists of nickel–chromium with resistivity of 1.5×10^{-6} Ω.m at room temperature (Serway) of a length 10cm and cross sectional are 4.2×10^{-8} m^2 a resistance of 4.3 Ohm was used to perform a helix with length 3.5cm of 4 turns each of radius of 0.25cm as shown in Fig. (3.8) was used as an infrared miniature source.

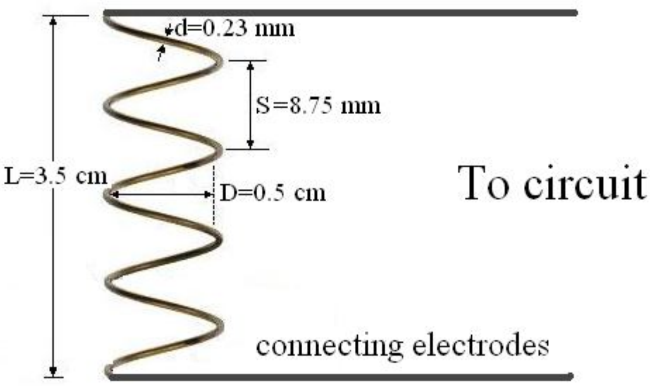


Fig.3.8: Schematic showing the Nichrome wire which was used as a miniature IR source.

3.5 Focusing devices

Miniature Infrared sources are considered as extremely very low power sources. So, wisely performing techniques to focus such radiation is needed to enhance their ability as spectroscopy source of radiation. In this work, available simple devices were used as converging instruments. Four different focusing methods were examined in order to get better infrared intensity; those methods are:

1) Using an aluminum tube
Tubes with suitable dimensions comparable to the wavelengths can act as wave guides to IR radiation. In present case a tube was used to increase the ability of focusing by collimating such rays by several internal reflections. To do so; an aluminum foil paper was used to cover the inner surface of a tube of radius R=8.3 mm and length L=5cm as shown in fig. (3.9).

Fig. 3.9: Photographs of an Al tube used for guiding the IR radiation.

2) A hemispherical shape reflector
A dome shaped with a smooth reflecting surface was used to examine focusing infrared radiation. With a radius of R=36.35mm and a depth of 22.95mm, as shown in fig. (3.10).

Fig.3.10: A schematic and photos from different sides showing the hemispherical shape reflector used for focusing IR radiation.

This converging focuser is already made reflector used in hand torch with a focal length of ~5cm.
3) Reflective mirror
A ZnSe coated flat mirror shown in Fig. (3.11) of radius R=12.75mm was used to reflect radiation emitted from the second side of the source back toward the detector. This type of mirrors is usually used as a laser reflector. It has a focal length of 1m. The aim here is to collect the backward emitted radiation and reflect it in the forward direction to enhance the power that could be used in a spectroscopy experiment.

Fig. 3.11: Photographs of the reflective ZnSe coated flat mirror.

4) Honey comb mesh shape reflector
A honey comb mesh shape is shown in Fig. (3.12) of diameter 93.7mm and height of 2cm with hexagonal shaped holes was placed at a distance of 4cm far away from the source and close to the detector was used also in order to study the effect of focusing. Using this simple inexpensive device for IR focusing was suggested by Laine (private communications).

Fig. 3.12: Photographs of the honey comb mesh shape which used in focusing the infrared radiation from miniature IR sources.

3.6 Applications

Infrared radiation has a wide range of applications; it can be used almost in different fields of life. Miniature infrared sources were studied and used in simple open to air experiments using source E as a one example. The experimental set up used to perform some applications is shown in Fig. (3.13), almost all applications were done following the same procedure.

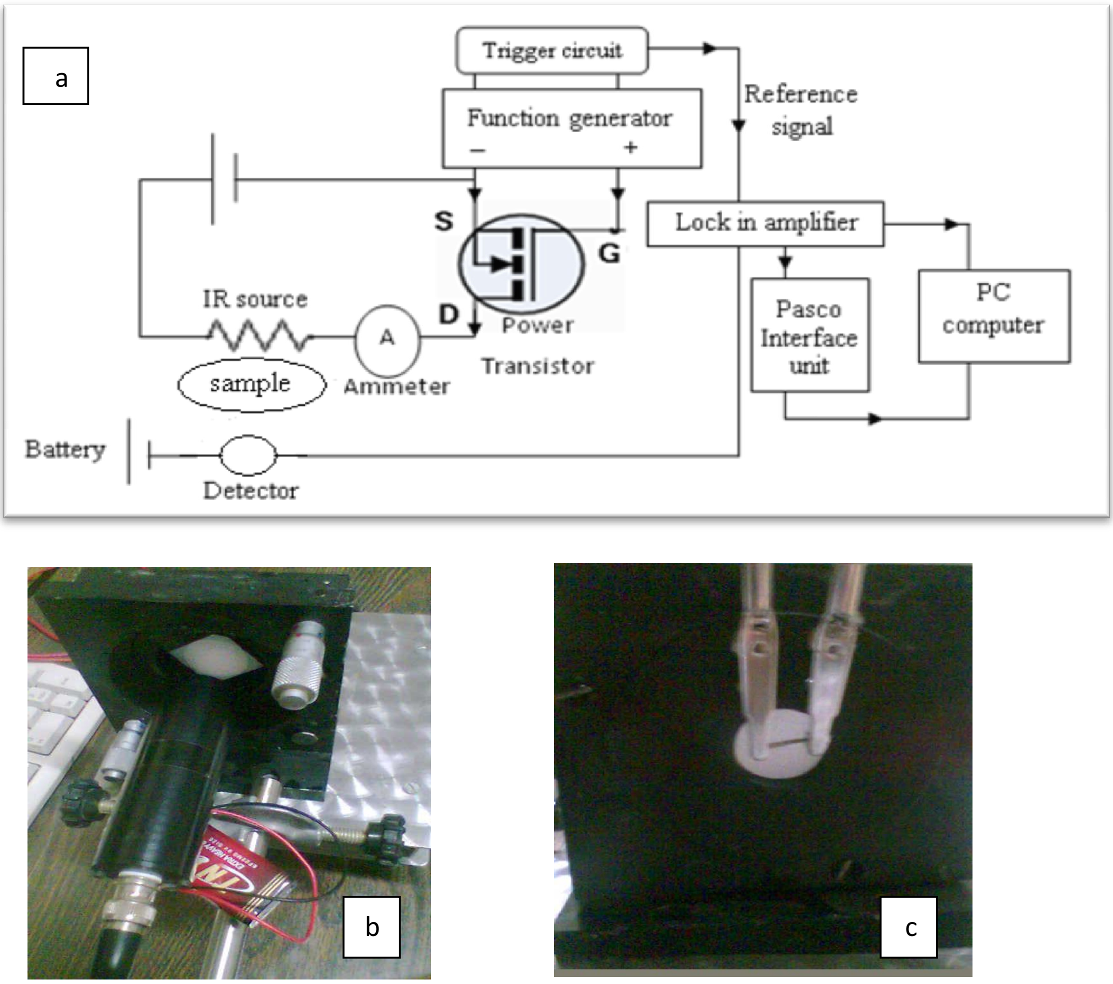


Fig. 3.13: a: A schematic showing the general set up for the applications
b: A photo of the experimental set up for applications
c: The position of the source in the used applications

Chapter four

Results

4.1 Introduction

In this chapter results obtained are presented. Characteristics of the infrared sources that were constructed from Fecralloy foils were examined. Another already manufactured structure such as a simple Nichrome wire was investigated for its ability for infrared emission and its dependence on distance. Different focusing methods such as aluminum tube interior coated, hemispherical shaped reflector, Honey comb mesh shape and front surface coated laser mirror were investigated for radiation enhancement. Some simple applications of the constructed infrared sources were studied and discussed using source E as an example of a Fecralloy infrared source.

4.2 Characteristics of Fecralloy infrared sources

Fecralloy foils composed of different elements at certain ratios (see section 3.4.1.) Characteristics of such sources were examined by studying the effect of different parameters such as distance; current and frequency on intensity of emitted IR radiation.

4.2.1. Distance dependence

In this experiment the dependence of IR radiation received by the detector on distance was studied. Frequency of the function generator was kept at 12Hz; since frequency of thermal pulses is found to be independent of area and must be low (Laine, 1997) and to avoid resonance with power supply; greatest common factors of 50 were neglected. Changing distance between source and detector; intensity was measured at different distances constant frequency and current. A photo of experiment arrangement is shown in Fig.(3.2b).

Graphs of intensity versus distance for sources C, D, E, F, G, H, J and K are plotted in figures 4.1a, b, c, d, e, f, g, and h, respectively. Fig. (4.1 i) shows a comparison between all sources.

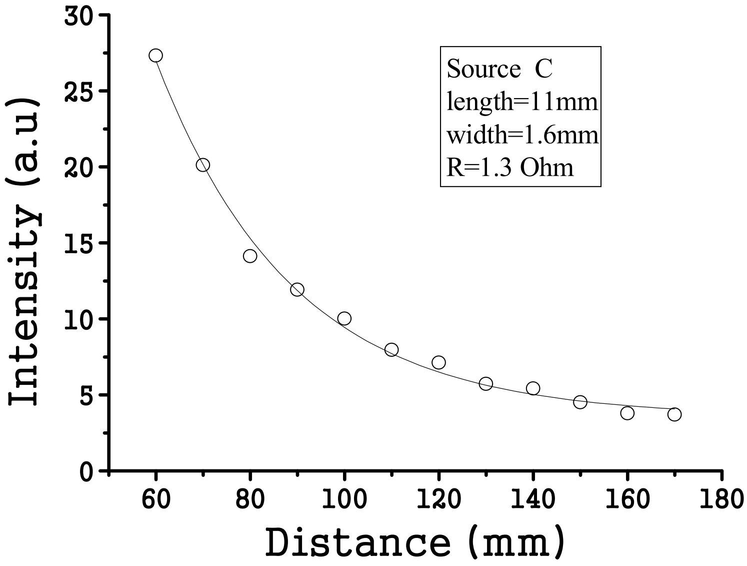


Fig.4.1 a: IR intensity versus distance for source C.

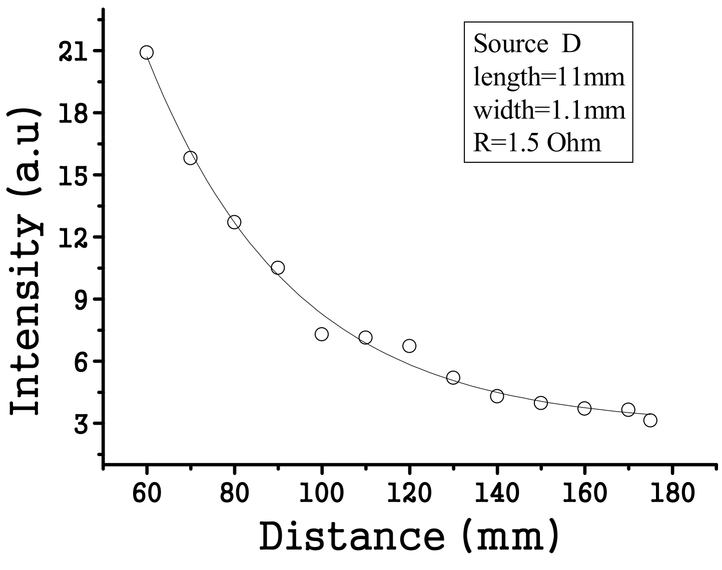


Fig.4.1 b: IR intensity versus distance for source D.

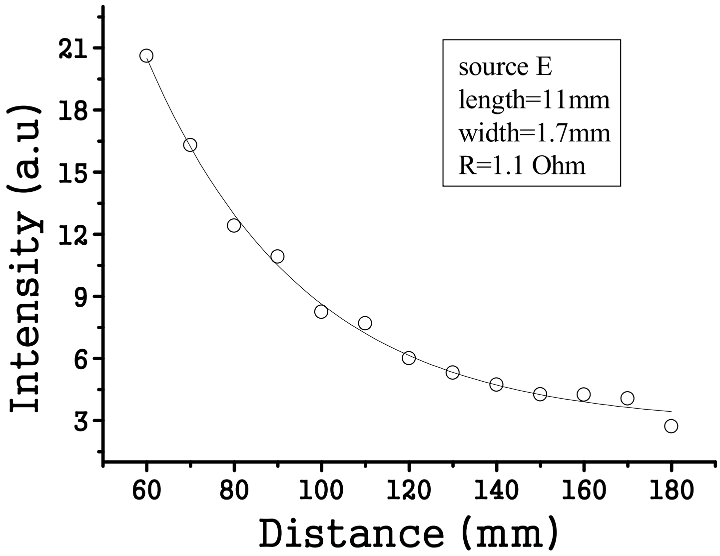


Fig.4.1 c: IR intensity versus distance for source E.

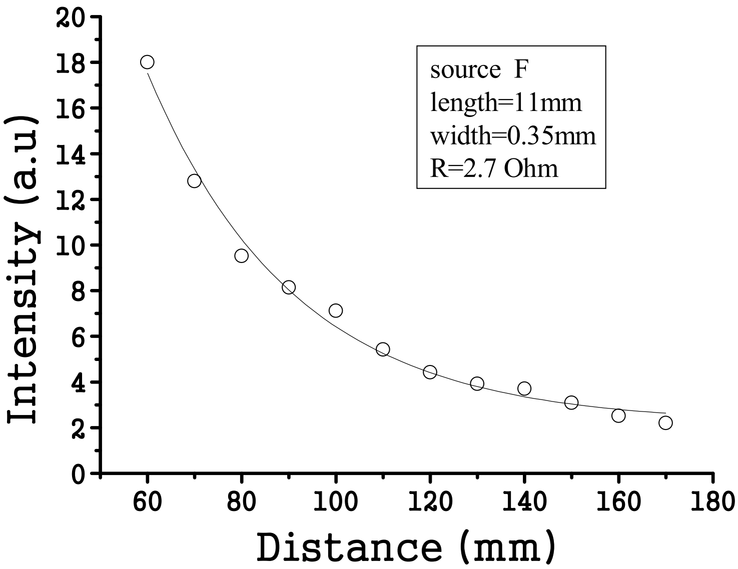


Fig.4.1 d: IR intensity versus distance for source F.

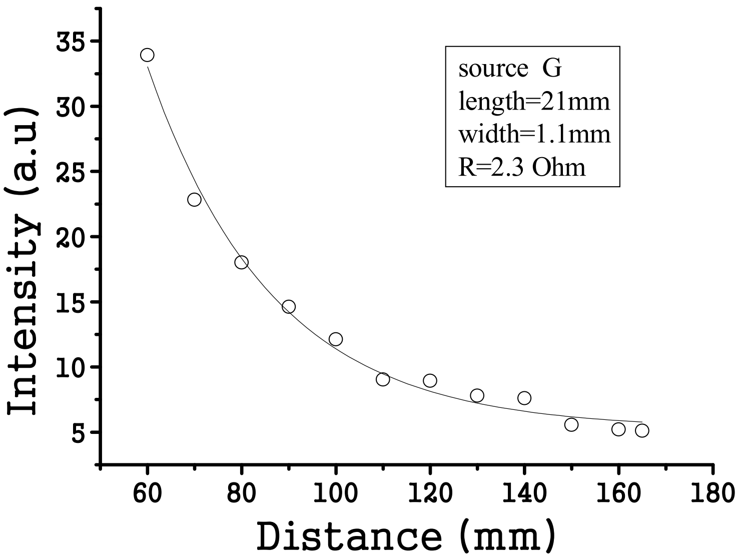


Fig.4.1 e: IR intensity versus distance for source G.

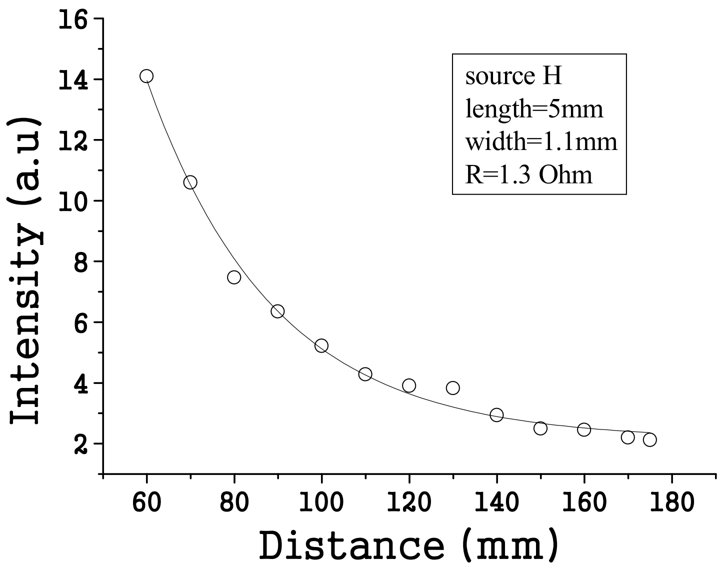


Fig.4.1 f: IR intensity versus distance for source H.

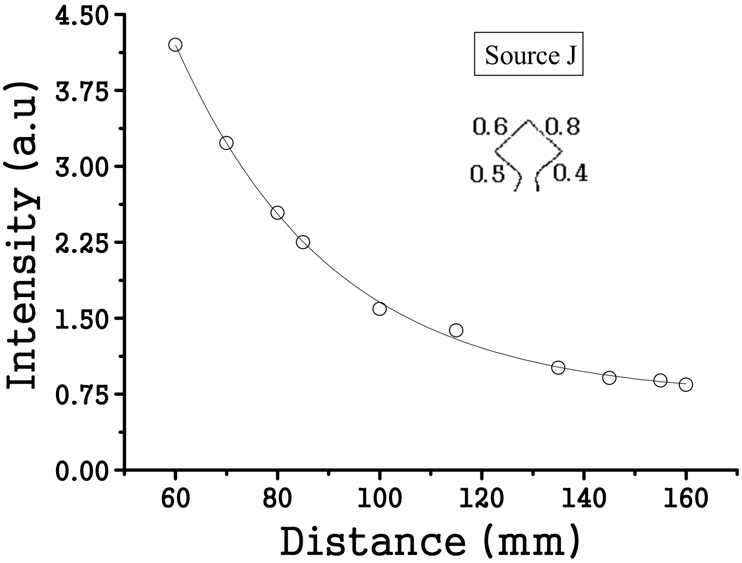


Fig.4.1 g: IR intensity versus distance for source J.

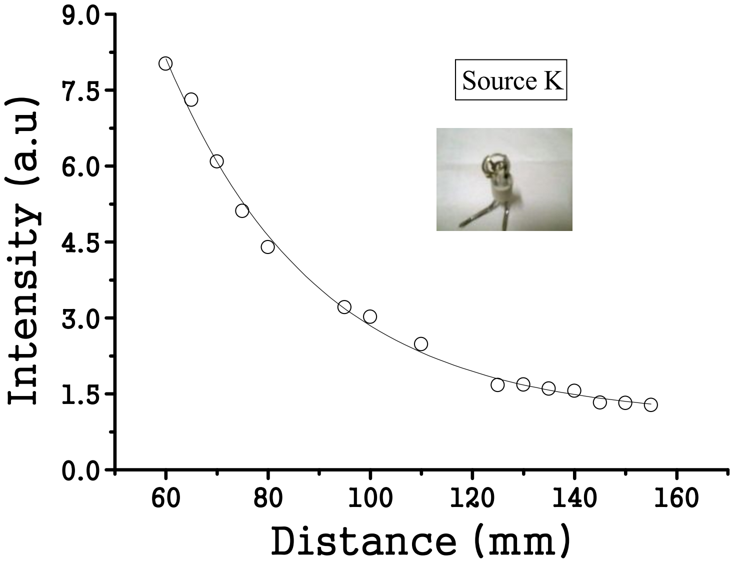


Fig.4.1 h: IR intensity versus distance for source K.

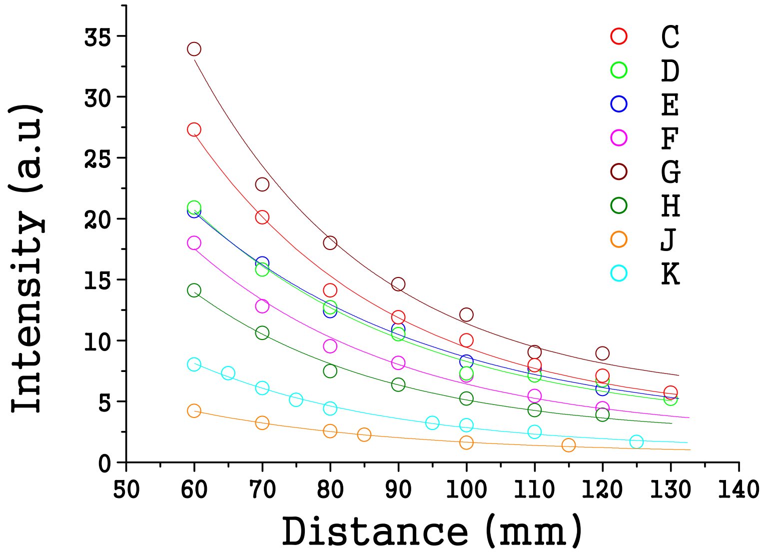


Fig. 4.1i: Comparison of intensity versus distance curves for a set of Fecralloy sources.

4.2.2. Current dependence:

Dependence of intensity on current was studied at 12 Hz when the source and the detector were placed 60mm apart. Current was increased until foil color dull red point is reached. Intensity is observed as before. Figures 4.2a, b, c, d, e, f, g and h show the dependence of intensity on current for sources C, D, E, F, G, H, J and K respectively:

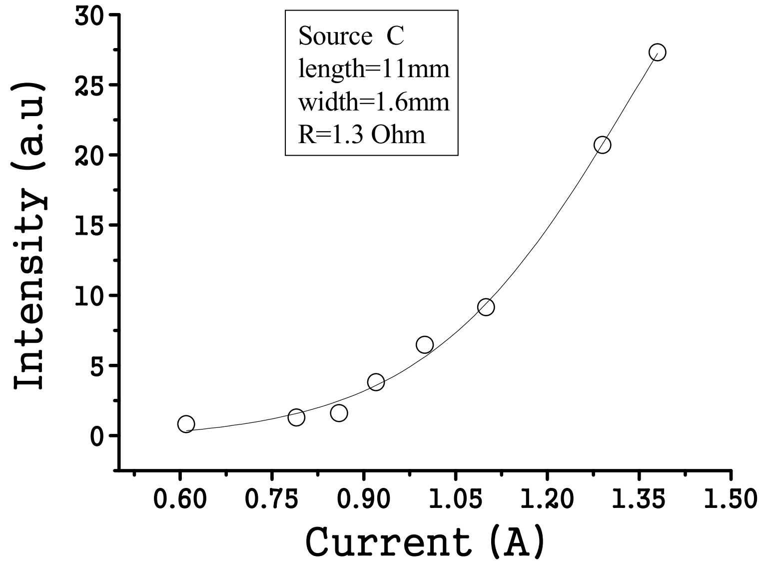


Fig.4.2 a: IR intensity versus current for source C.

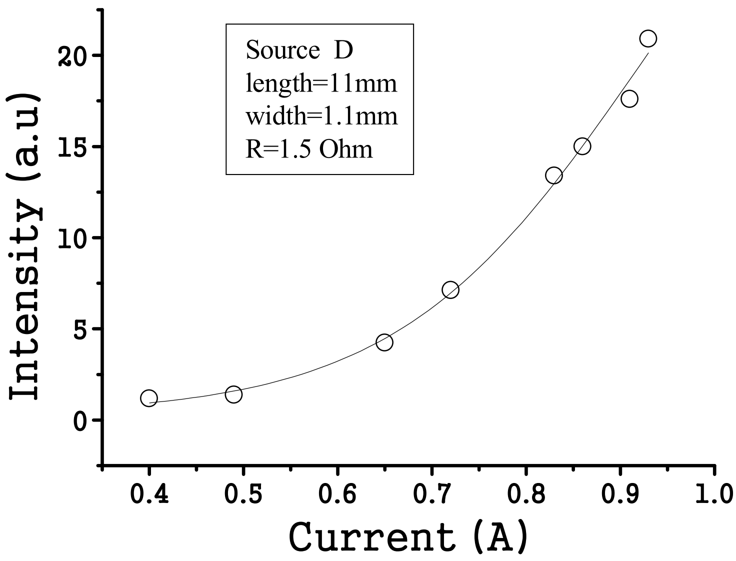


Fig.4.2 b: IR intensity versus Current for source D.

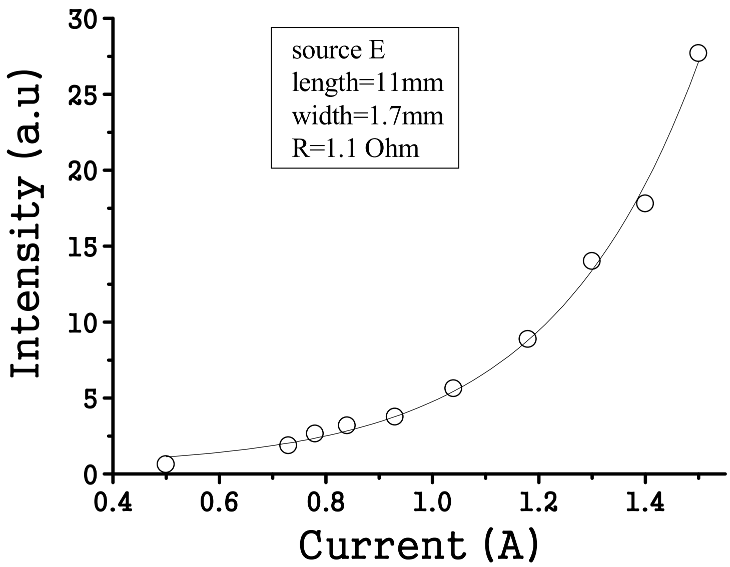


Fig.4.2 c: IR intensity versus current for source E.

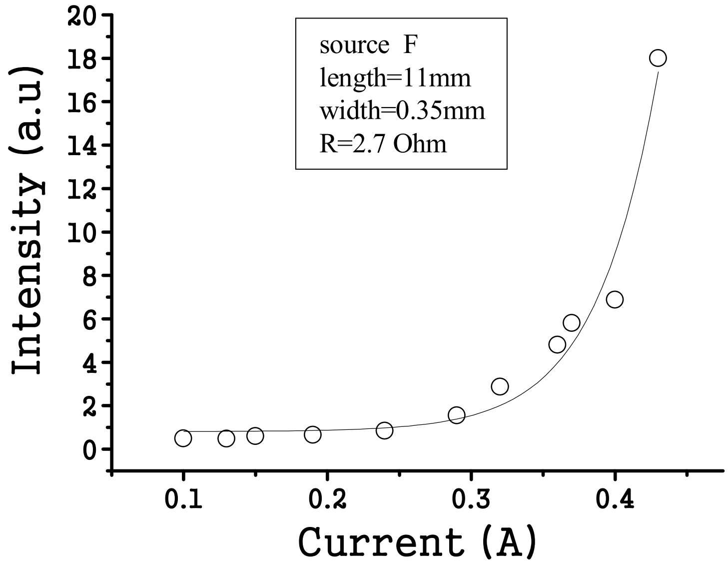


Fig.4.2 d: IR intensity versus current for source F.

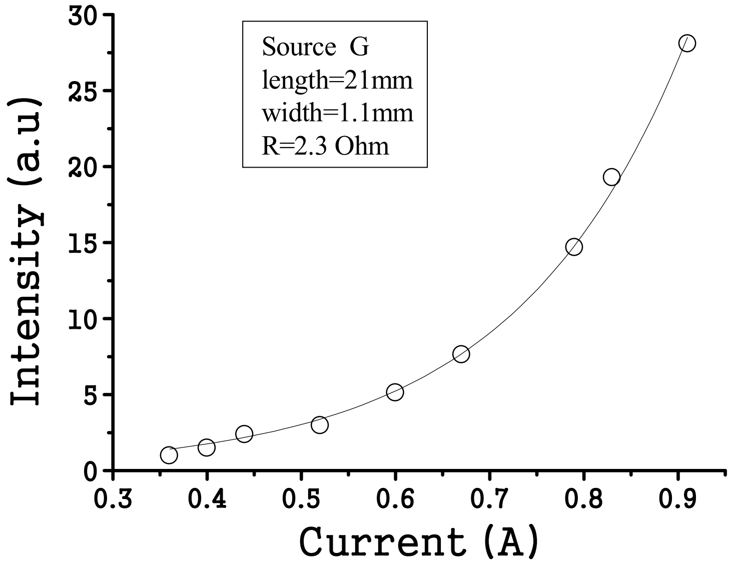


Fig.4.2 e: IR intensity versus current for source G.

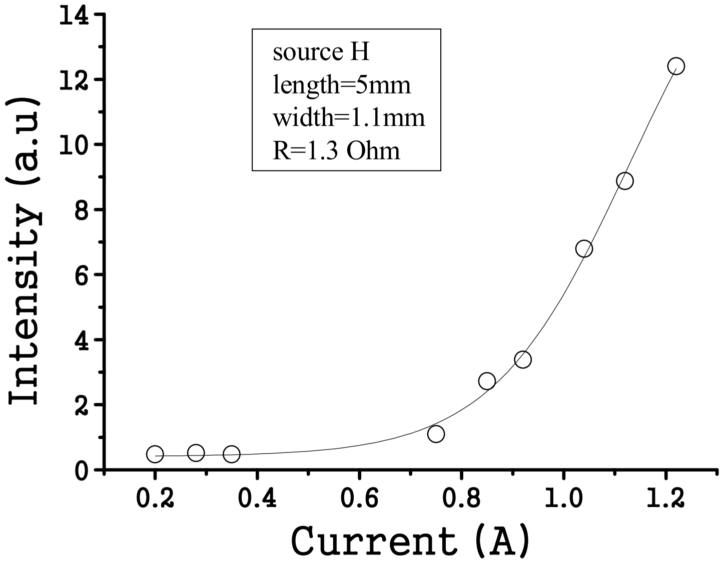


Fig.4.2 f: IR intensity versus current for source H.

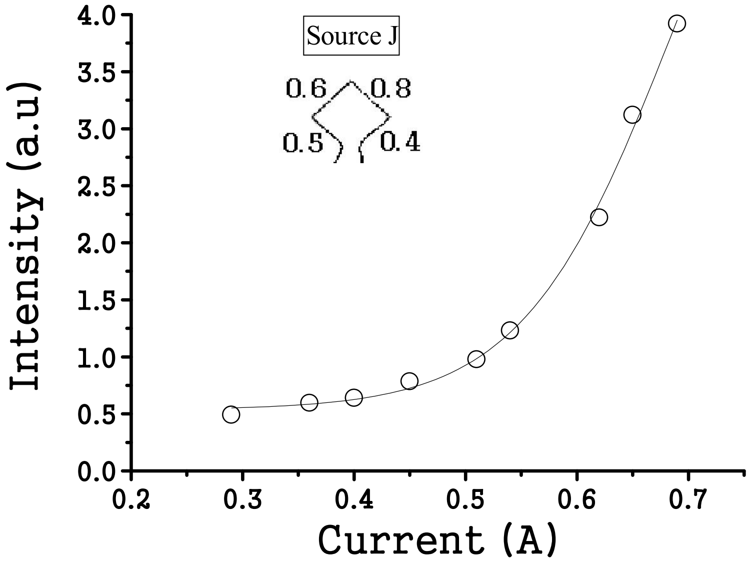


Fig.4.2 g: IR intensity versus current for source J.

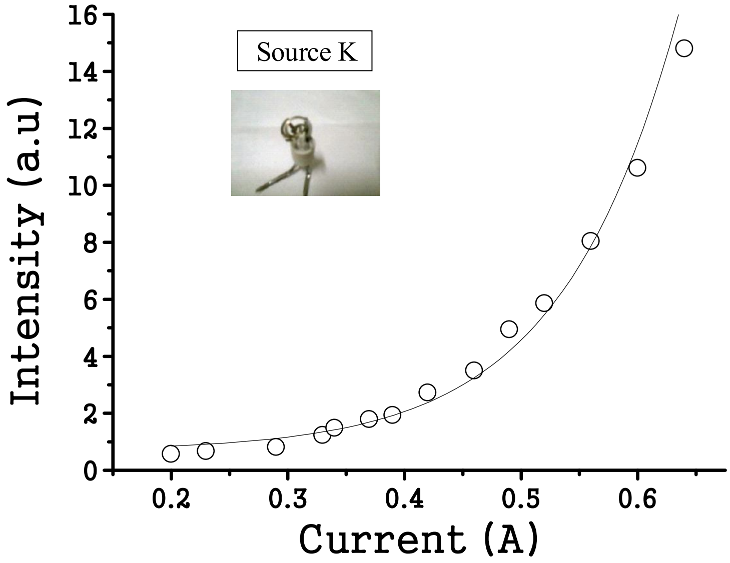


Fig.4.2 h: IR intensity versus current for source K.

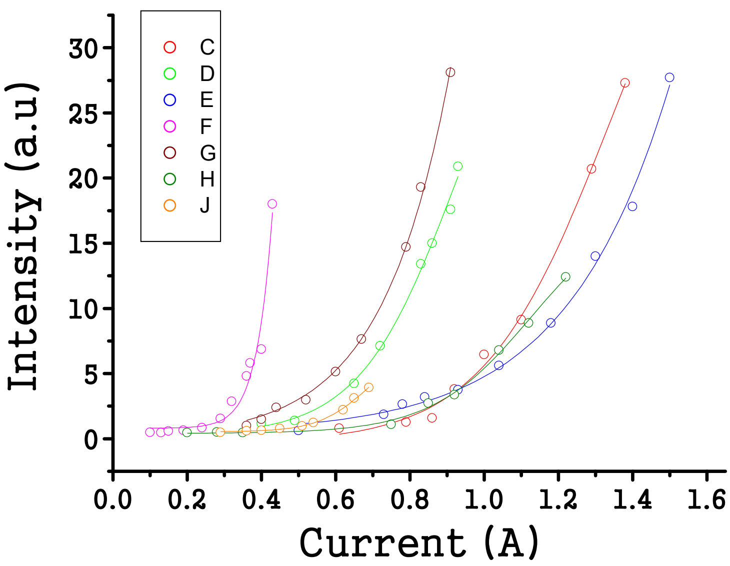


Fig. 4.2 i: Comparison of intensity versus current curves for a set of Fecralloy sources.

4.2.3. Frequency dependence:

To examine the Dependence of intensity on frequency; the detector and source were placed 60mm apart and the frequency is changed, Figures 4.3a, b, c, d, e, f, g and h show the relation between intensity and frequency for sources C, D, E, F, G, H, J, and K respectively.

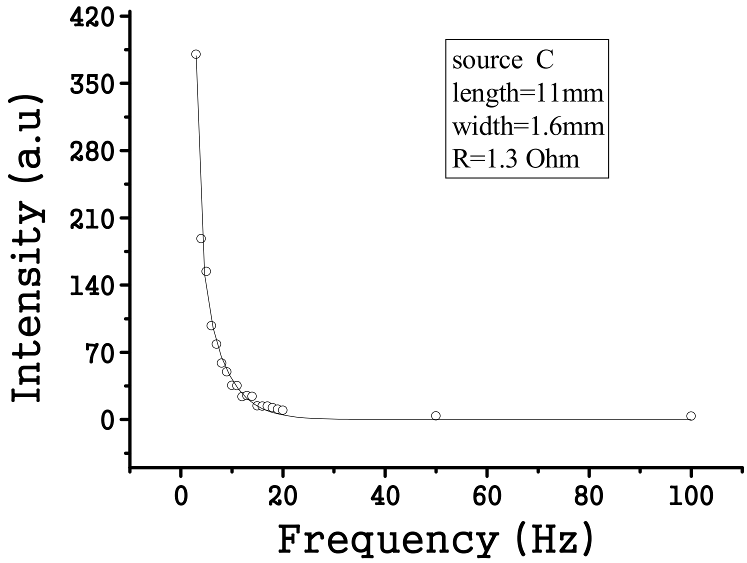


Fig.4.3 a: IR intensity versus frequency for source C.

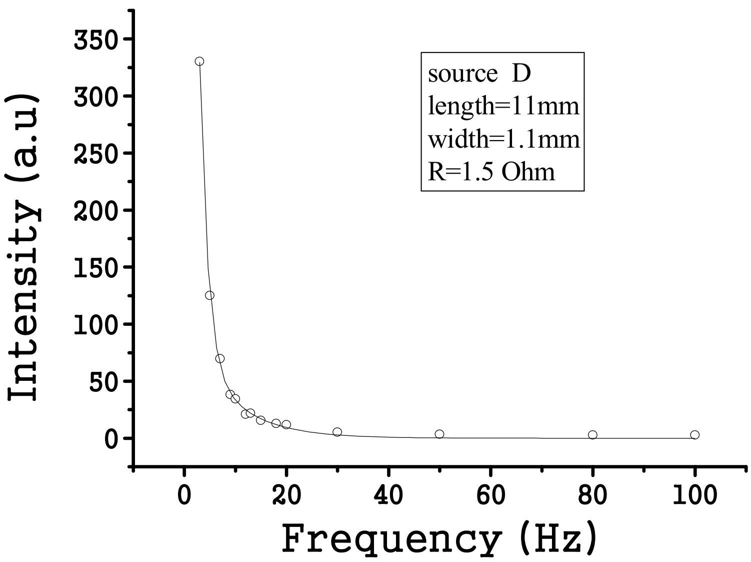


Fig.4.3 b: IR intensity versus Frequency for source D.

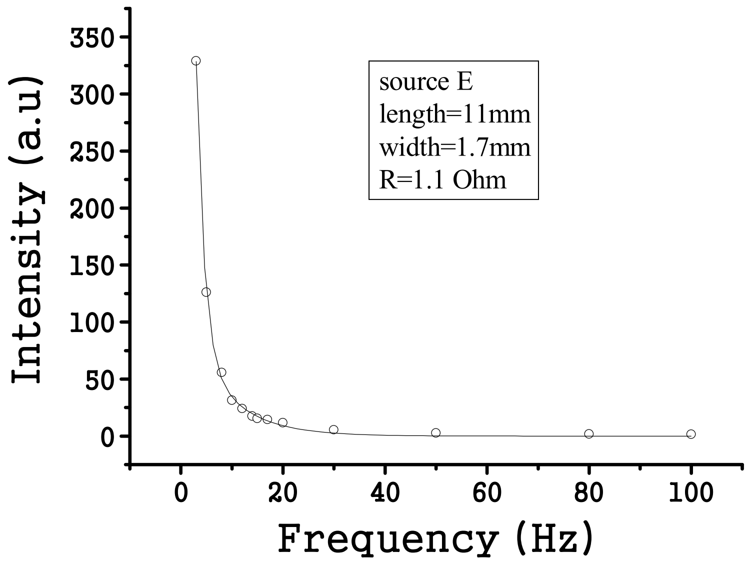


Fig.4.3 c: IR intensity versus frequency for source E.

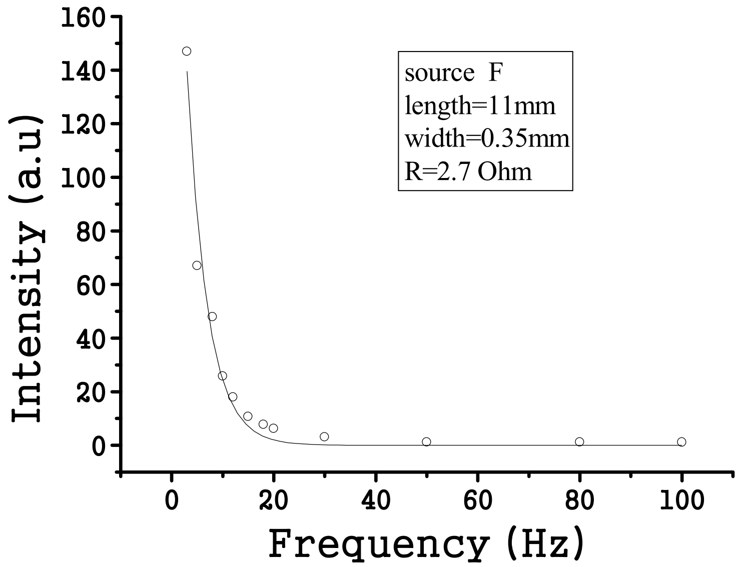


Fig.4.3 d: IR intensity versus frequency for source F.

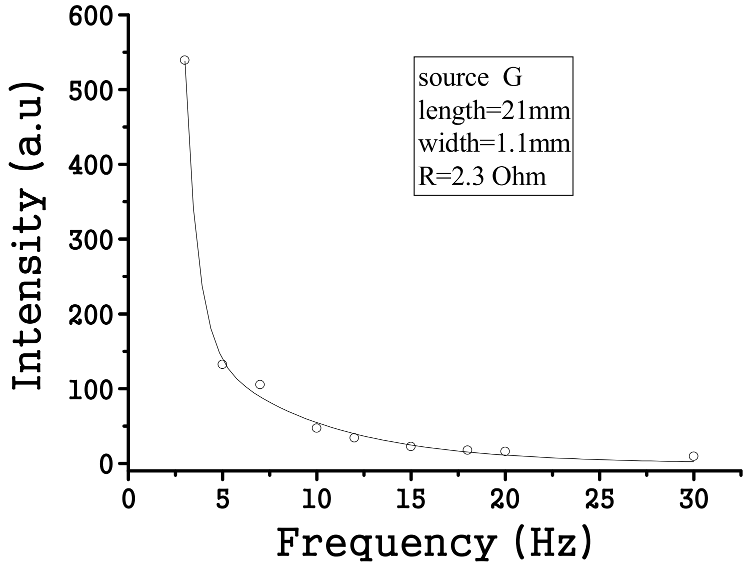


Fig.4.3 e: IR intensity versus frequency for source G

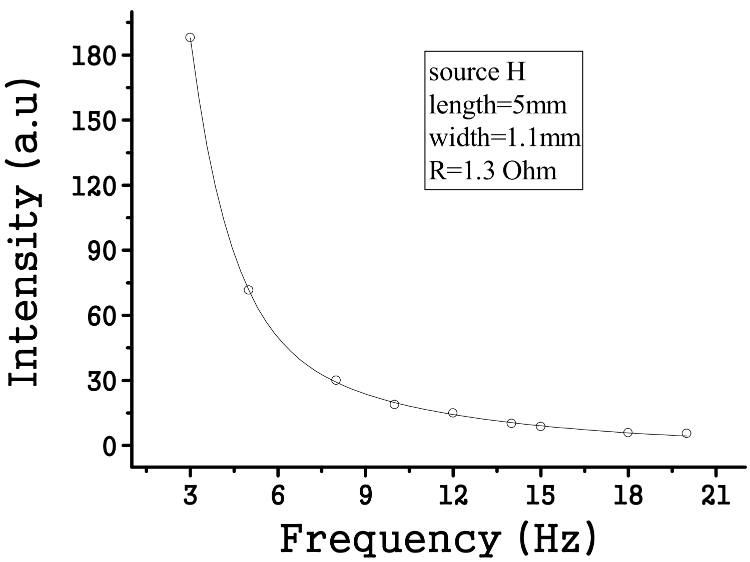


Fig.4.3 f: IR intensity versus frequency for source H.

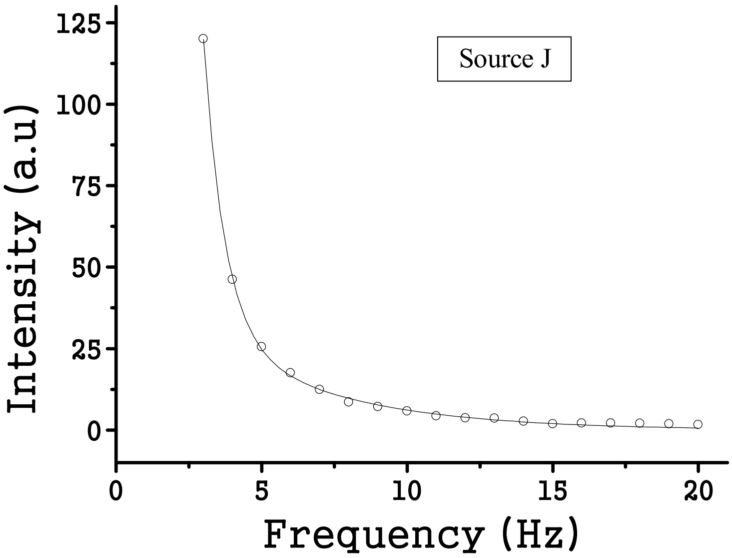


Fig.4.3 g: IR intensity versus frequency for source J.

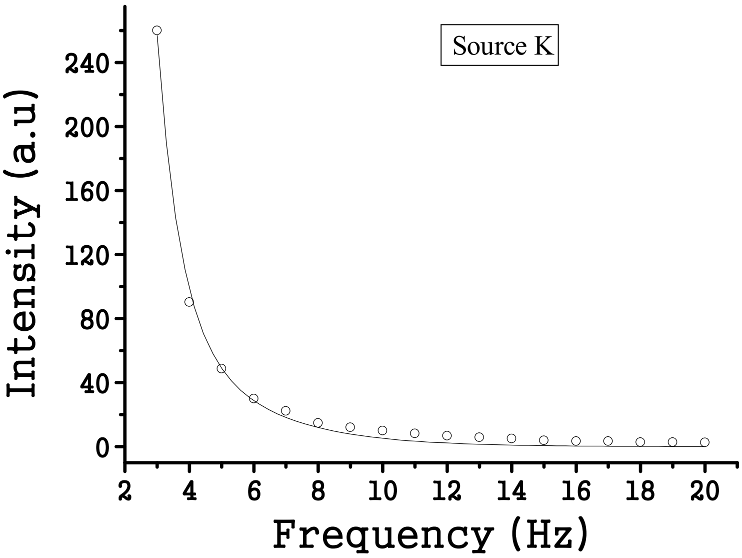


Fig.4.3 h: IR intensity versus frequency for source K.

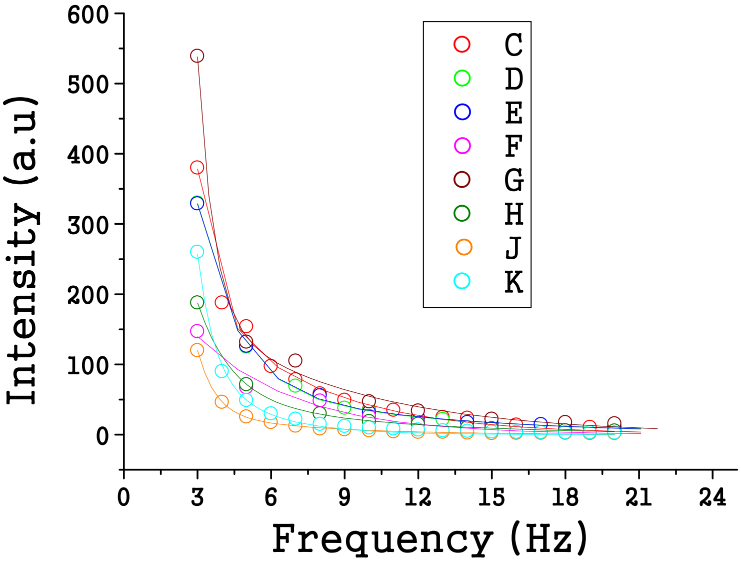


Fig. 4.3 i: Comparison of intensity versus frequency curves for a set of Fecralloy sources.

4.2.4. Angle dependence

Fig. (4.4) shows the effect of detector position with respect to the source, i.e. the angle between line drawn perpendicular to center of source and that to the surface of the detector window. The source was fixed at the zero point of a graduated mobile circle and the detector was fixed on the outside moving part of the circle such that it can be moved easily to a chosen angle.

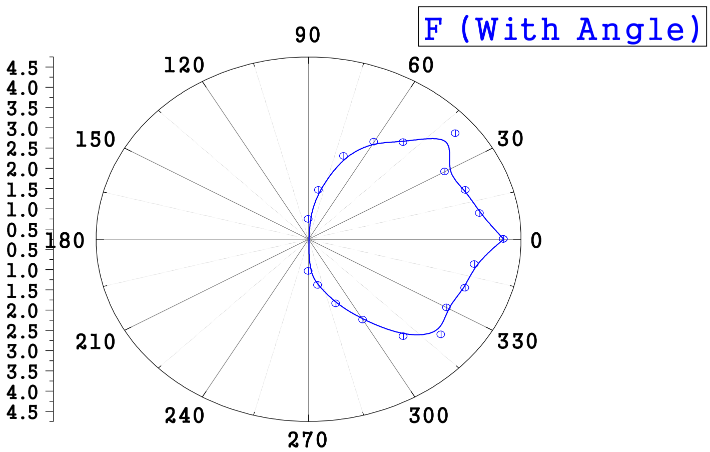


Fig.4.4: Dependence of IR intensity on the angle between the vertical axis to the foil and detector

4.3 Effect of length and width of active source element

Two groups of IR sources were constructed, the first group (sources C, D and F) has the same length (11mm) but different widths, the second group (sources D, G, and H) have the same width (1.1 mm) but different lengths. The study aims to investigate the different parameters of the active same element, i.e. Fecralloy on the emitted intensity from the source

4.3.1. Constant length group:

Fig. (4.5) shows the dependence of infrared intensity on distance for constant length sources having different widths; i.e. sources C, D and F.

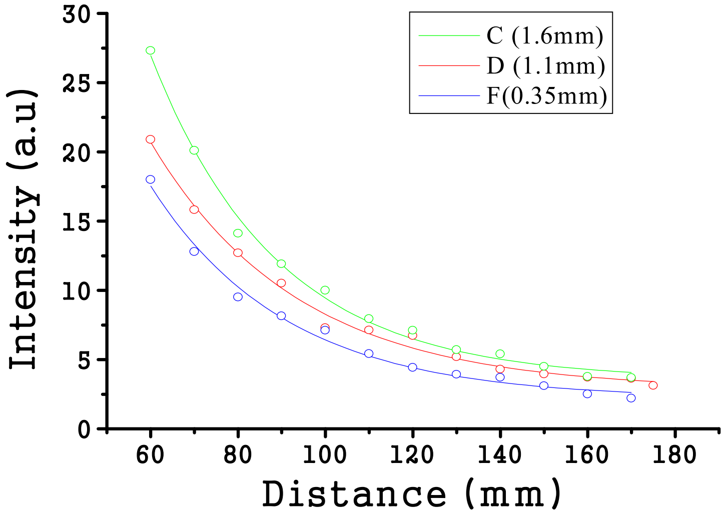


Fig.4.5: Comparison of Intensity versus distance for different IR source having the same length and different widths

The dependence of intensity on current at constant frequency (12 Hz) and constant distance (60mm) between sources and detector is shown in Fig. (4.6).

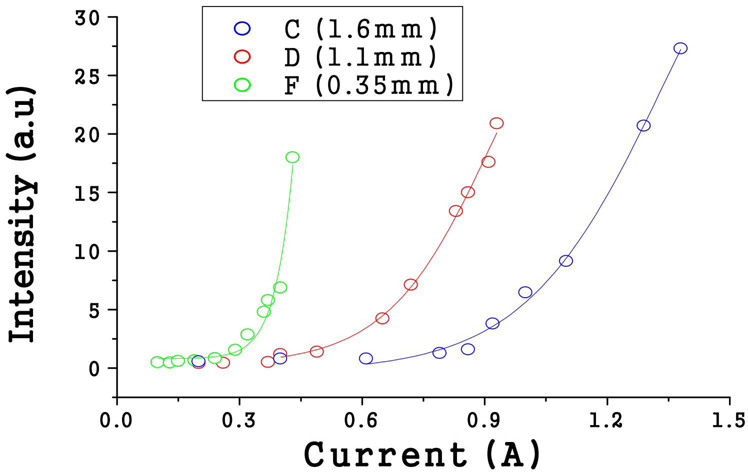


Fig.4.6: Dependence of intensity on current for different IR sources having the same length but different in widths.

Figure (4.7) shows the dependence of intensity on frequency for same length sources.

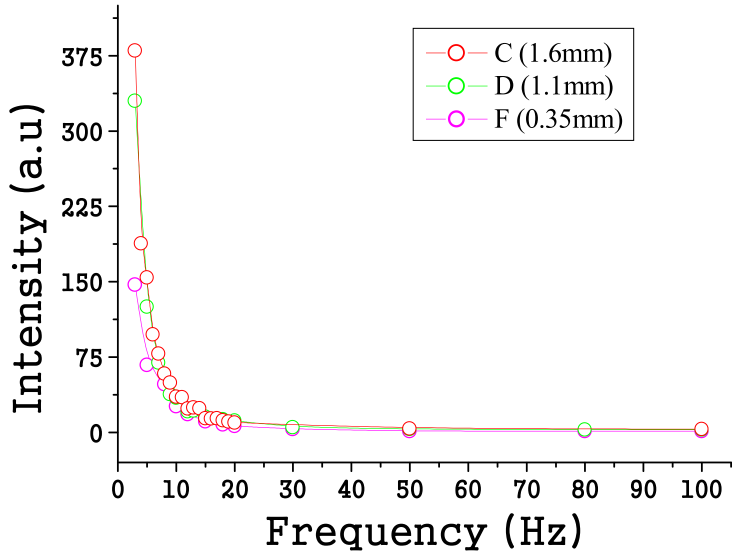


Fig.4.7: Dependence of intensity on frequency for different IR sources having the same length but different in widths

4.3.2. Constant width group:

The effect of changing length of same width foils also is studied; the following three figures: 4.8 a, b and c show the dependence of intensity on distance, current and frequency respectively for same width and different lengths foils:

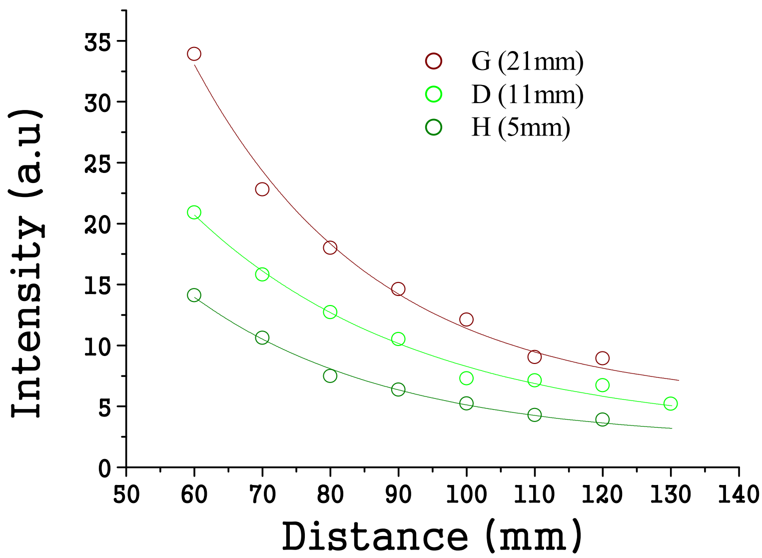


Fig.4.8 a: Dependence of intensity on distance for different IR sources having the same width but different in length.

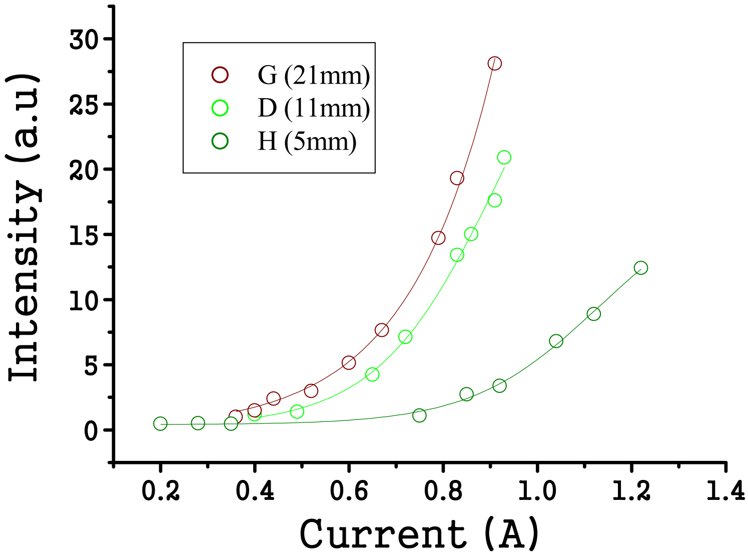


Fig.4.8 b: Dependence of intensity on current for different IR sources having the same width but different in lengths.

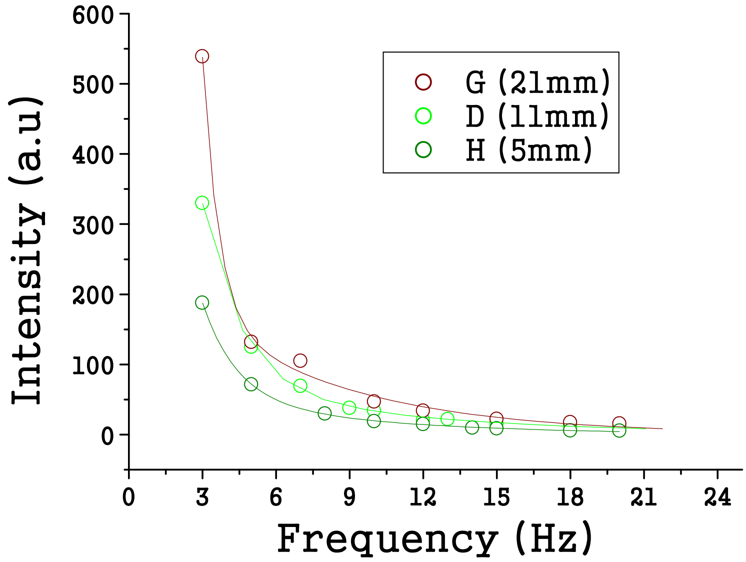


Fig.4.8 c: Dependence of intensity on frequency for different IR sources having the same width but different in lengths.

4.4 Focusing methods

Usually the miniature infrared sources are low power sources, they emit in the µW region. Even at this low power; they are very useful for molecular spectroscopy. Intensity collimation to enhance the power is advantageous. Figures (4.9a) to (4.9 d) show the results of using different methods to get higher intensity levels by focusing the infrared radiation.

4.4.1. Using an aluminum tube:

Fig. (4.9a) shows the result of using the aluminum tube method in focusing IR radiation from the source. Intensity versus distance characteristics for source E at 12 Hz using the aluminum tube as a guide compared with that without focusing. The source was located in front of one side of the tube. The detector was located 35mm far away from the other side of the tube.

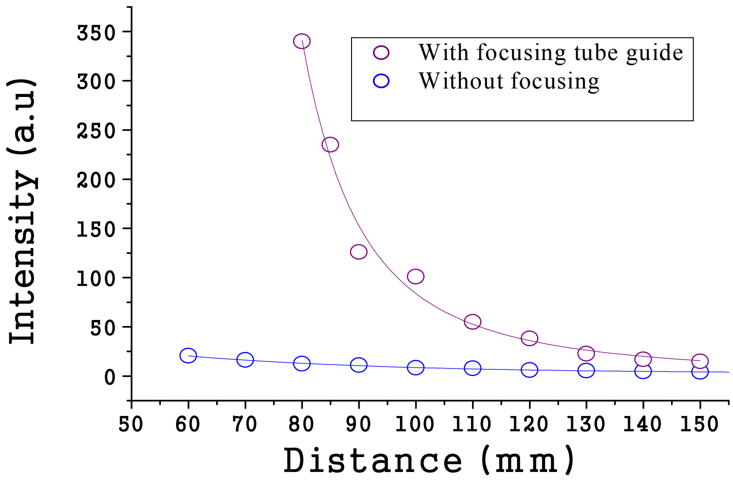


Fig.4.9 a: IR intensity versus distance for source E before and after focusing tube guide was used.

4.4.2. A hemispherical shaped reflector:

In Figure (4.9 b) the hemispherical shape reflector method is used; Source E was placed at the bottom center of this reflector.

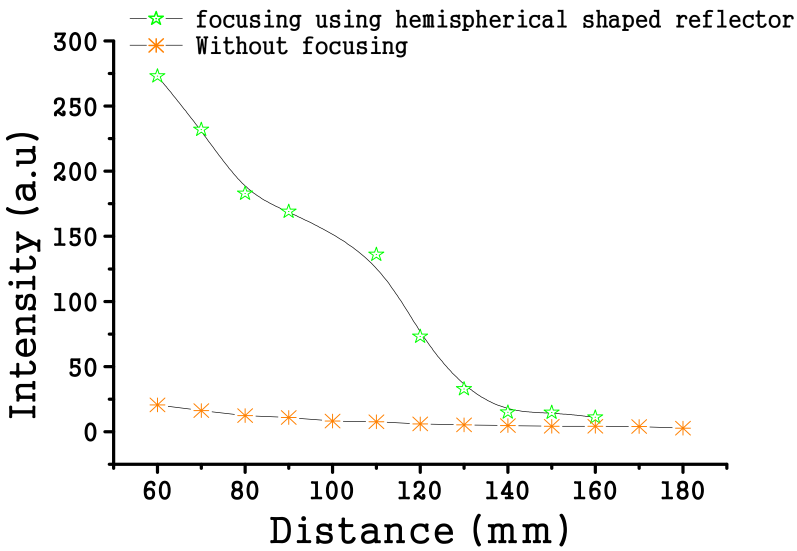


Fig.4.9 b: IR intensity versus distance for source E compared to that after using the hemispherical shaped focusing device

4.4.3. Honey comb mesh shape:

The honey comb mesh of diameter 93.7mm and height of 2cm with hexagonal shaped holes was used as a focuser. A simple experiment was used to find the point of focusing of this device and it was approximately 17cm away from it. This equipment was placed at a distance of 4cm far away from the source and close to the detector was used also in order to study the effect on focusing. Fig. (4.9 c) shows another method for focusing which is using Honey comb mesh shape.

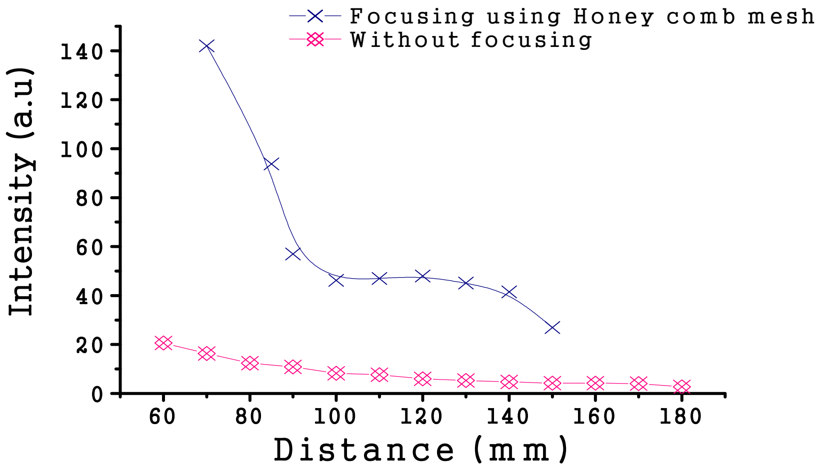


Fig.4.9 c: IR intensity versus distance for source E compared to that after using the Honey comb mesh shape for focusing radiation

4.4.4. Reflective mirror:

A coated reflecting mirror was also used as a reflector to collect infrared radiation; Fig. (4.9 d) shows the effect of using it on intensity versus distance; the mirror was placed just behind the source. Detector was initially placed 60mm far away from the source.

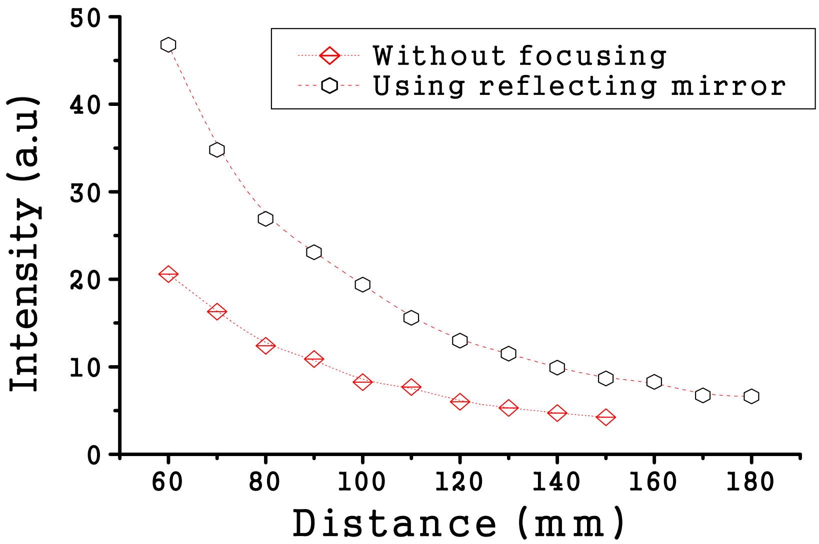


Fig.4.9 d: IR intensity versus distance for source E compared to that after using the coated reflecting mirror for focusing radiation.

All methods of focusing are compared as shown in Fig.(4.9 e) to the original graph without any effect.

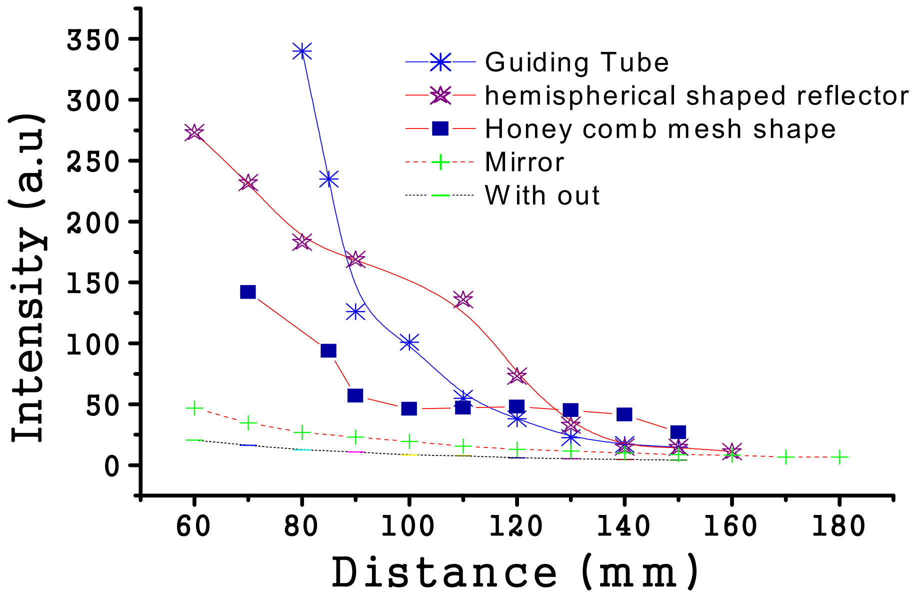


Fig.4.9 e: Comparison between different focusing methods.

4.5 Other infrared miniature sources (Nichrome wire)

Simple components such as a Nichrome wire can be used as an infrared source; by passing current through such components; such a wire was formed on the shape of helix. A graph of intensity versus distance at frequency of 12 Hz is shown in Fig. (4.10).

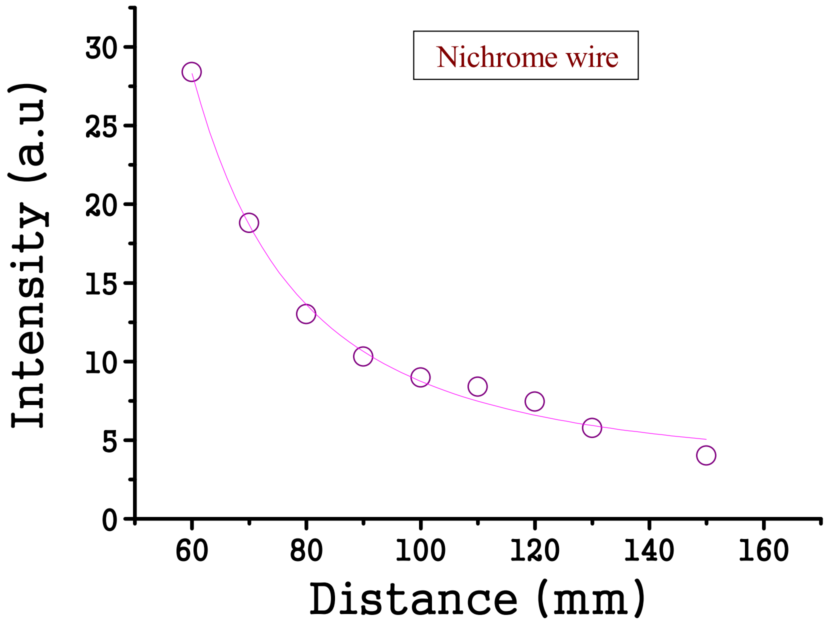


Fig.4.10: Characteristics of intensity versus distance for helix shaped Nichrome wire.

Fig. (4.11) shows a comparison of intensity versus distance curves for all used sources.

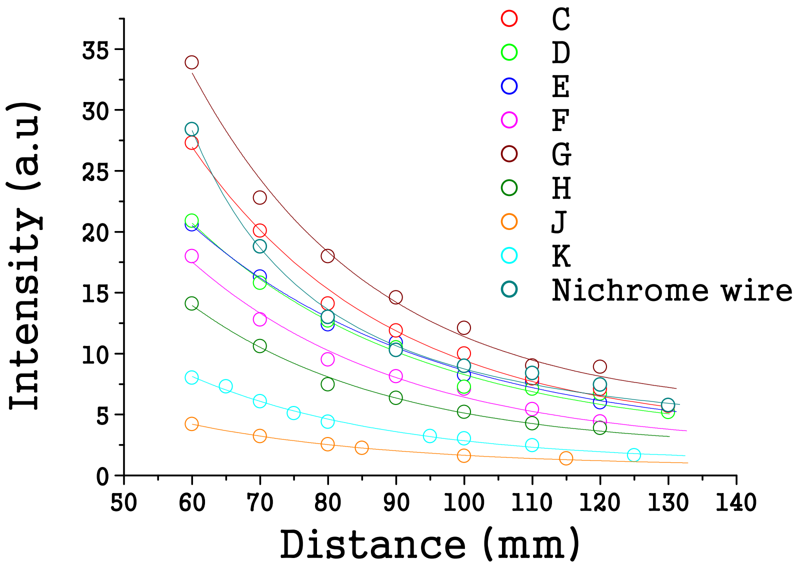


Fig. 4.11: Comparison of intensity versus distance curves between all miniature infrared used sources.

4.6 Applications

One of the important aims of this work was to construct miniature infrared sources suitable for compact detection systems dependant on principles of spectroscopy. In this section a set of applications is carried out using some of the constructed sources as an example of the different applications that can be performed with such sources. The general set up used for such applications is shown in Fig. (3.14), the following applications have been carried out:

4.6.1. Liquid absorption of IR radiation:

A small piece of paper ($3x3cm^2$) was immersed in different Liquids such as different types of oils, water and glycerin. The same area ~$20.2mm^2$ of wetted paper was subjected to IR radiation in front of the source which was located 11.3mm from the front side of paper and the detector was initially located at 20mm from the other side. The Transmitted infrared radiation through the paper was examined and compared with each other. Fig. (4.12) shows the characteristics of the transmitted infrared through the immersed paper with different types of liquids: sesame oil, black cumin oil, Olive oil, glycerin and water.

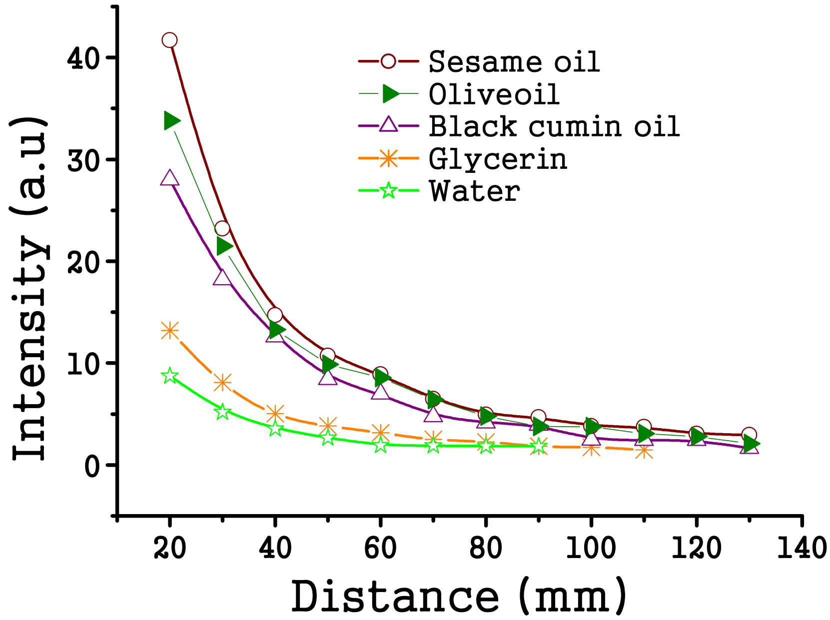


Fig.4.12: Comparison of infrared transmittance through pieces of papers immersed in different liquids.

4.6.2. Effect of heat on oil properties:

No doubt that oil properties change with heat. Oil was heated for certain time intervals and sample on a piece of cloth from each time interval was studied. The result is shown in Fig. (4.13).

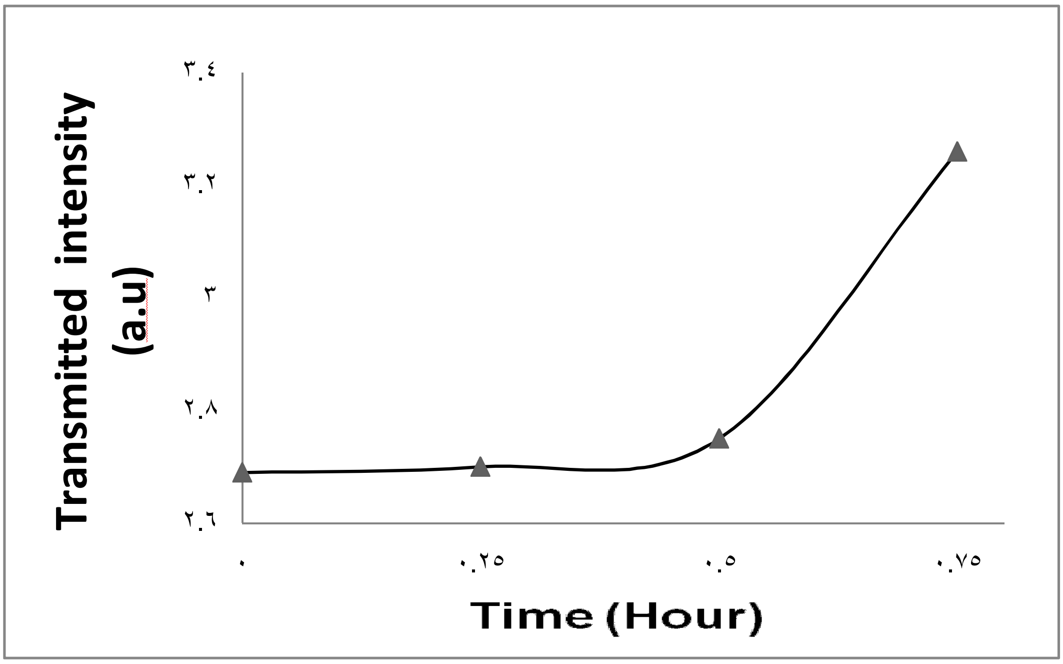


Fig.4.13: Effect of heating time of absorption of infrared radiation by vegetable oil heated for different times.

4.6.3. IR absorption by different dye concentrations:

Dye with ratios 1:2:3:4 was added to 7 ml of water to get different degrees of red solutions concentrations which are used to dye a broadcloth piece of ($3\times3cm^2$) the cloth pieces were then examined in the same way as the above experiment. Fig.(4.14) illustrates the effect of dye ratios on IR absorption.

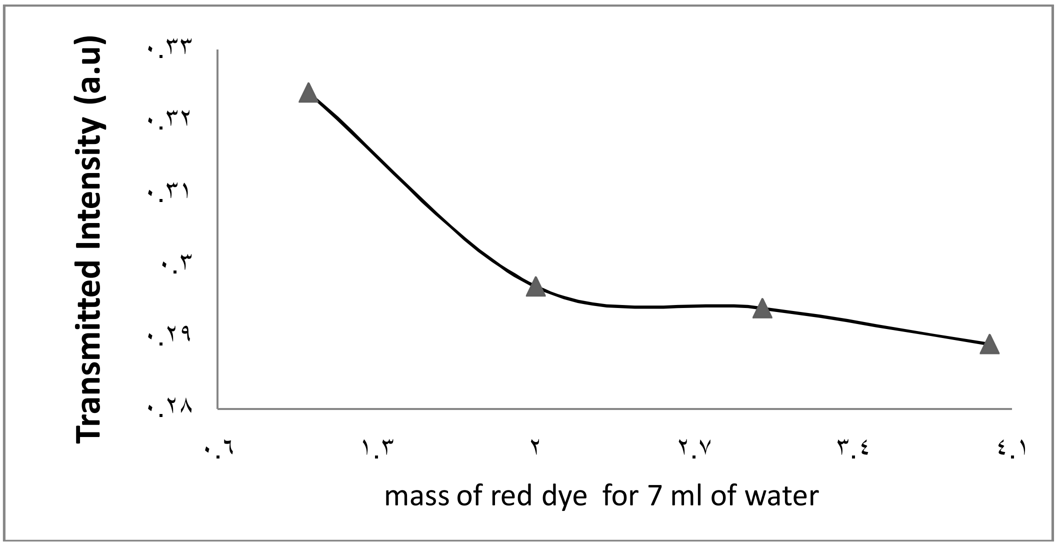


Fig.4.14: Dependence of transmitted infrared radiation on dye concentration.

4.6.4. Detection of olive oil adulteration with vegetable oil:

Olive oil an expensive healthy material is a target for adulteration. In this work; olive oil was mixed with vegetable oil at different ratios: 1:1 up to 10:1; the effect of this mixture on IR transmittance was studied by detecting the transmitted infrared radiation from the immersed cloth piece of ($3\times3cm^2$) in different sample mixtures. The effect is denoted in Fig. (4.15).

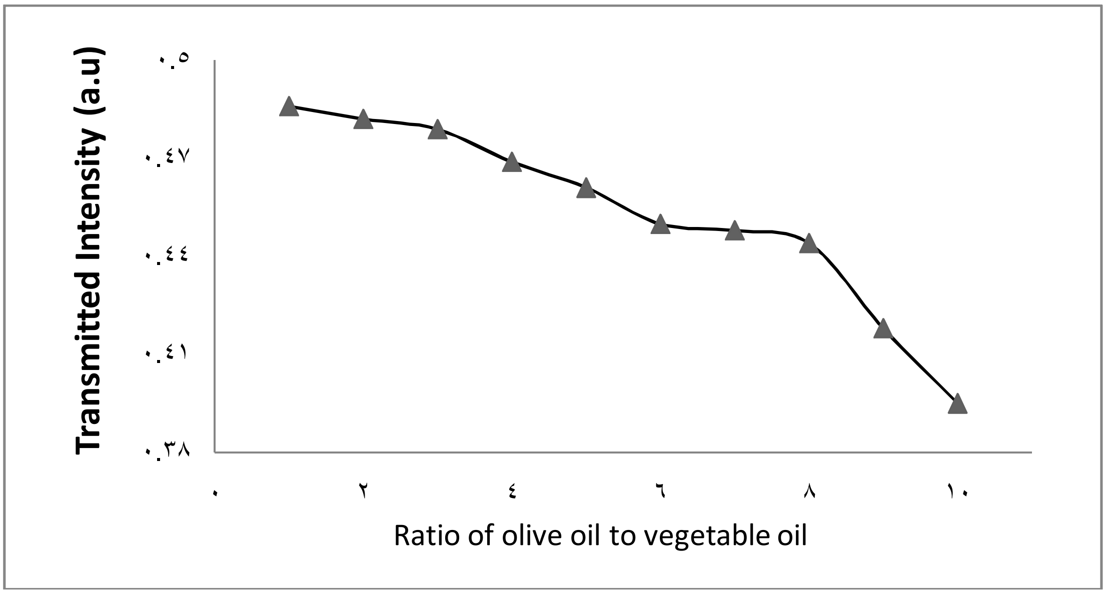


Fig.4.15: Effect of mixing vegetable oil with olive oil at different ratios.

Chapter five

Discussion

5.1 Introduction

Characteristics of IR sources are very important; they can be used in many useful applications. Properties of these sources will be determined and simplified; this will facilitate the usage of these sources in applications and it will probably encourage others to improve these sources to be used in better ways. Using simple and obtainable objects as an infrared source is a good method which saves money and efforts. Simple Focusing methods using uncomplicated items will be compared so that they will be used in applications depending on the required needs. Sources were used in simple applications; these humble instructive applications can be developed to be used in complex valuable applications.

5.2 Characteristics of Fecralloy infrared sources

From figures 4.1a to 4.1 h; it's clear that the shapes of intensity versus distance curves are the same for all sources irrespective of their shape. As the distance increases the intensity decreases exponentially. This can be explained as: when the detector is moved away from the source infrared is diverged on all sides of the source so that the detected intensity is decreased. More than that; some of the radiation will be absorbed by air. A power fit was done for the graphs; it was found that intensity obeys the relation:

$$I=I_o/r^b \tag{5.1}$$

With r is the distance, I_o is a constant represents the maximum intensity; b is another constant ranging from 1.66 for source J to 2 for source K. For other sources the value is near 2; that is the relation can be compared to the relation between intensity of light and distance d; Radiation intensity decreases in inverse proportion to the square of the distance between the detector used and the radiating body (Freitag, 1989)

$$I = \frac{K}{d^2} \tag{5.2}$$

Graphs of intensity versus distance power fitting for sources C, D, E, F, G, H, J and K are plotted in figures 5.1a, b, c, d, e, f, g and h respectively.

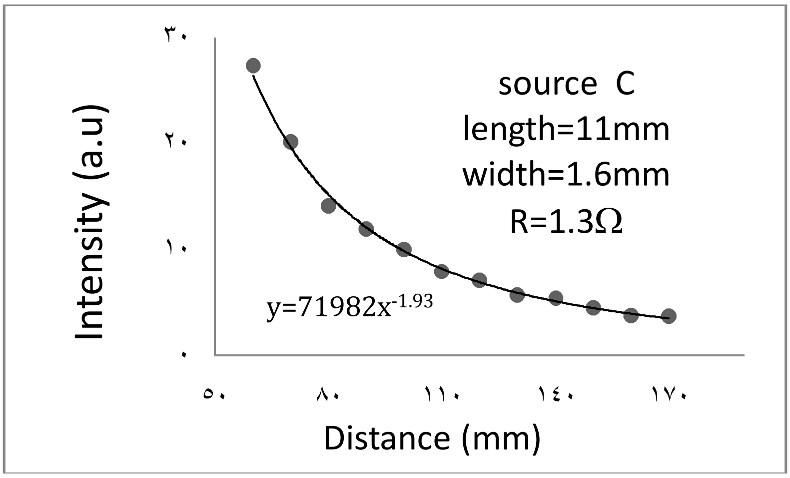


Fig.5.1 a: Power fit of intensity versus distance for source C.

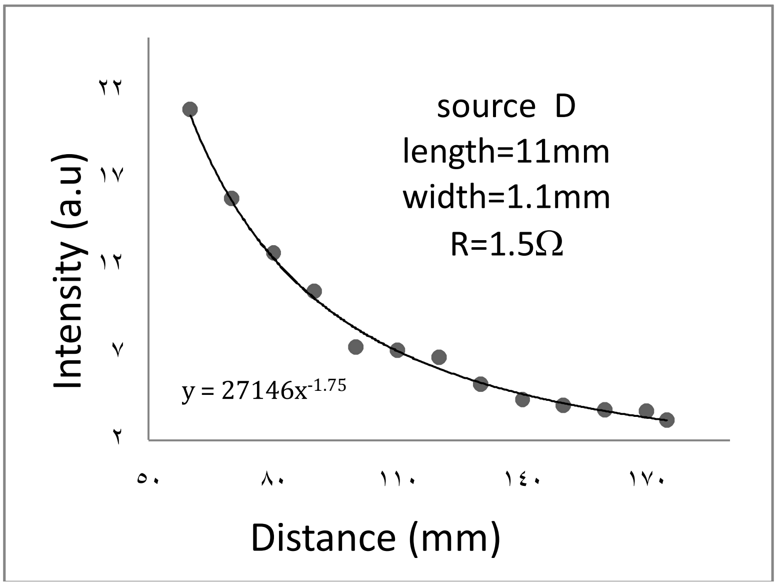


Fig.5.1 b: Power fit of intensity versus distance for source D.

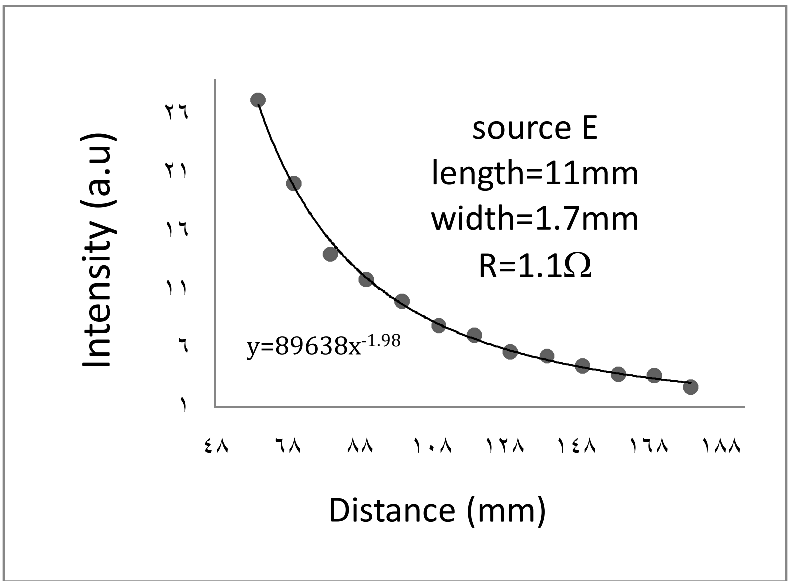


Fig.5.1 c: Power fit of intensity versus distance for source E.

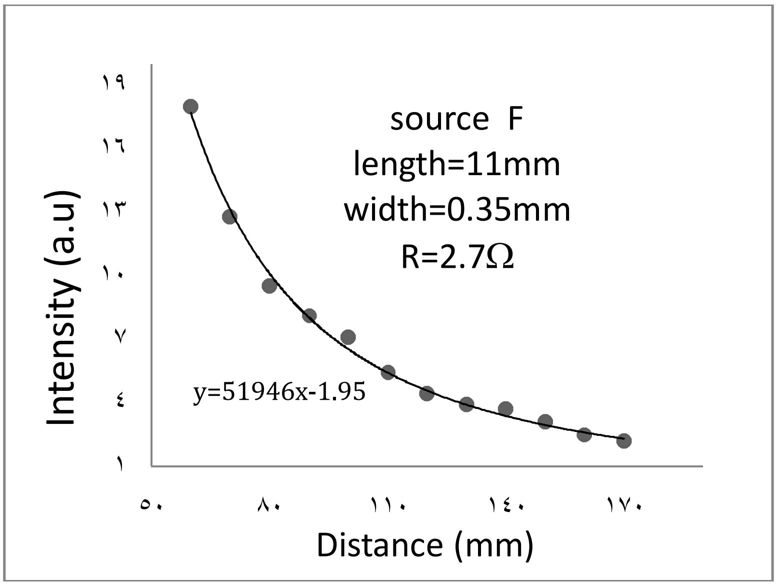


Fig.5.1 d: Power fit of intensity versus distance for source F.

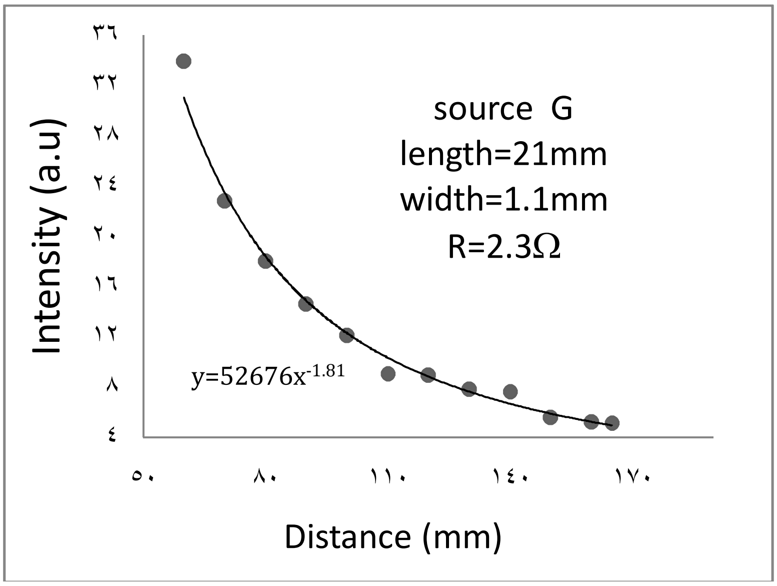


Fig.5.1 e: Power fit of intensity versus distance for source G.

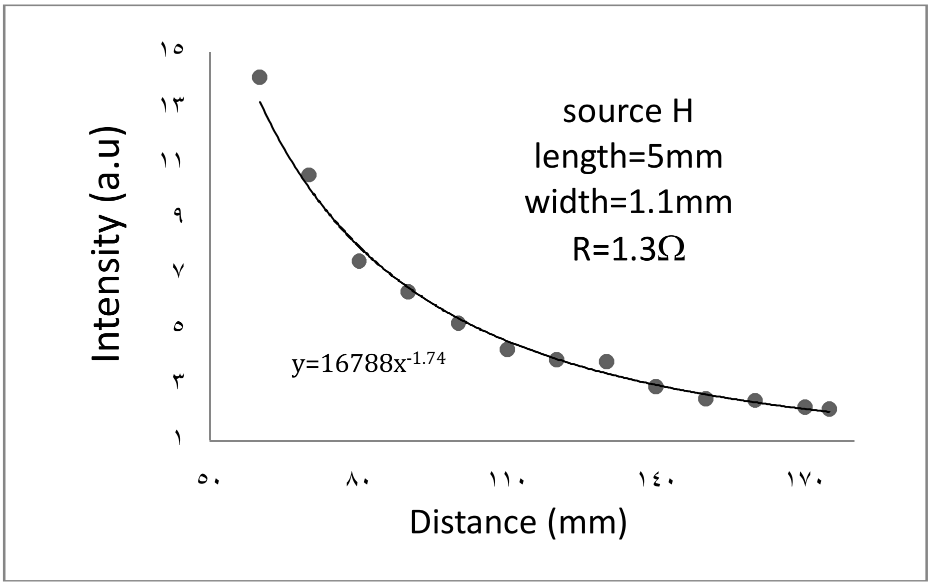


Fig.5.1 f: Power fit of intensity versus distance for source H.

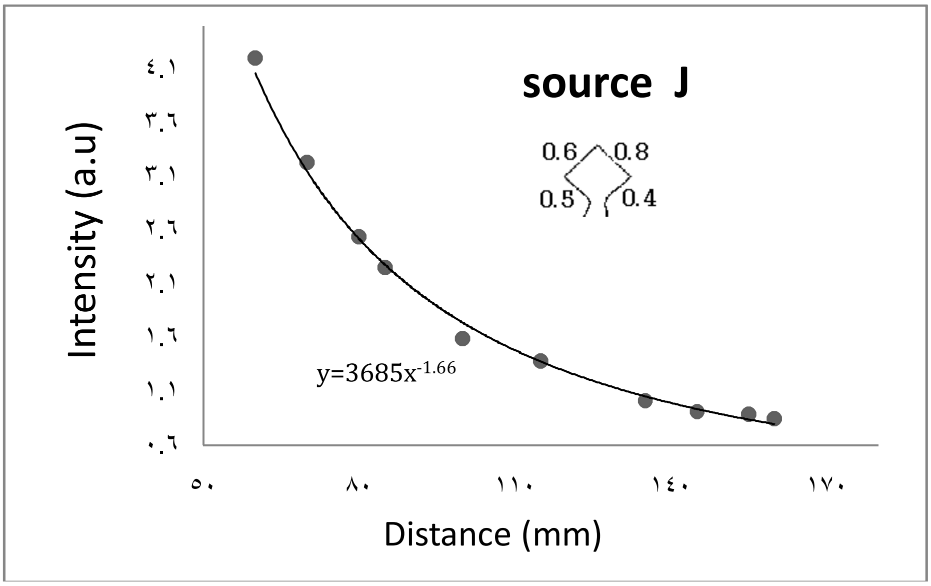


Fig.5.1 g: Power fit of intensity versus distance for source J.

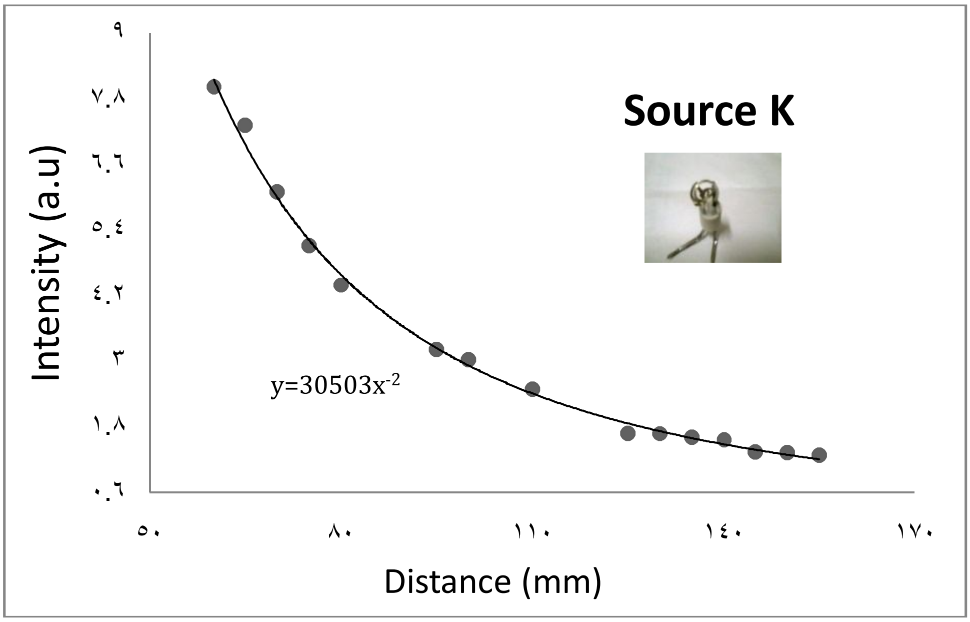


Fig.5.1 h: Power fit of intensity versus distance for source K.

The maximum intensity depends on the size of the foil, and current passing through it.
The relation between current and intensity is obvious, and has the same shape fashion for all sources in spite of the shape of the source. Figures 4.2a, b, c, d, e, f, g, and h show the dependence of intensity on current for sources C, D, E, F, G, H, J and K respectively: it's clear that increasing the current will increase the intensity of infrared radiation, as increasing the current will increase the temperature which means increasing the emitted radiation from source (higher temperatures lead to more emission and to better sources (Smith, 2002).

Increasing the applied frequency; results in decreasing the intensity rapidly as shown in Figures 4.3a, b, c, d, e, f, g and h for sources C, D, E, F, G, H, J, and K respectively. The intensity for low frequencies is high; for those in order to emit infrared radiation at small frequencies, larger current must be applied, as the frequency increases; the current decreases. The frequency of thermal pulses is given by equation 2.11. The vibration of the foil will affect the resistance and current obviously. For large frequencies the intensity is almost constant and approximately zero; for those high frequencies the heat is continuous and the self cooling process does not appear clearly. For frequency range (10-20) Hz the current of each source was approximately constant so that the intensity is almost constant.

Fig. (4.4) shows the effect of the position of the detector on the intensity detected for source F. Polar plot was used. It's found that Maximum intensity was attained when the source and the detector were on the same line that is the angle is zero; which guarantees small divergence of infrared radiation.

5.3 Effect of length and width of Fecralloy sources on intensity

Fig.(4.5) shows the dependence of infrared intensity versus distance for same length sources: it is obvious that as the width of the sheet increases the intensity is shifted up that is increased; this can be explained from the fact that when the surface area increases the amount of the emitted radiation will increase (see equation 2.9 chapter 2).

It is clear from Fig. (4.6) that as the current increases; the intensity also increases rapidly. As the current increases; the temperature of the foil will increase; i.e. more infrared radiation will be emitted. It's clear that for sources having the same length but different widths, intensity increases with increasing the width; as wider sources have more emitting areas that is more emitted radiation. This also can be explained as the area increases the resistance decreases that is the current increases which appears clearly in the figure.

Fig. (4.7) shows the dependence of intensity on frequency, as the frequency increases the intensity decreases rapidly. The curves almost the same for the sources, that is for same frequency the same intensity was detected; since the current to get infrared changes as the frequency changes; the vibration of the foil will affect the resistance and current. Also as the frequency increases; the time needed for self cooling decreases then nearly continuous spectrum will appear.

From figures: 4.8 a, 4.8 b, 4.8 c. one can see clearly that as the length increases the intensity increases; which can be explained as the area increases the emitted radiation will increase. Fig. (4.8 b) shows that as the length increases the line of the figure is shifted up and this is related to the previous reason. The left shift is related to the fact that increasing the length will increase the resistance of the foil and this will decrease the current which is needed to infrared radiation emission. Fig. (4.8 c) also shows that as the length increases the intensity increases but with small difference since the current needed to reach the threshold for infrared emission depends on frequency and differs from source to another. For frequency range (10-20) Hz the current of each source was approximately constant the effect of the length on intensity is clear. It is advantageous to use low frequencies; to achieve self cooling process.

5.4 Focusing methods

5.4.1. Using an Aluminum tube:

This method of using the aluminum tube in focusing was a successful way; results showing the effectiveness of this method are shown in fig. (4.9 b) the intensity at small distances is 27 times greater than the original intensity and this is related to the soft reflector aluminum paper which used to cover the inner surface of the tube, as Aluminum is a naturally shining metal that is used as a reflector (Edwards, 1934) as shown in Fig. (5.1).

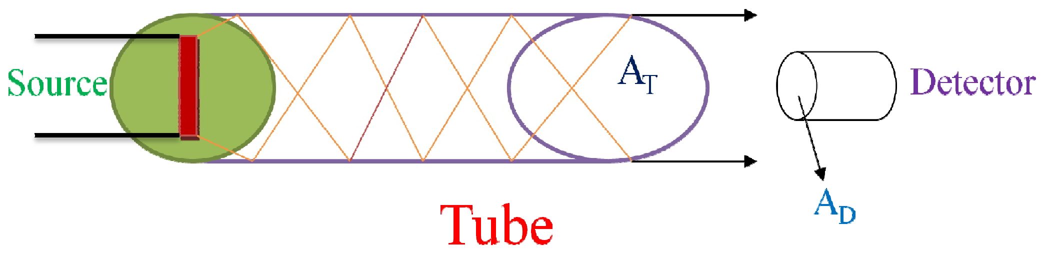


Fig. 5.1: Sketch of reflected rays on the surface of inner coated Al tube.

Incident infrared will be reflected on the internal surfaces and collected to leave the tube with a converged infrared beam that reaches the detector. On the other hand; removing the tube will make rays diverge and small ratio of them will reach the detector as shown in Fig. (5.2).

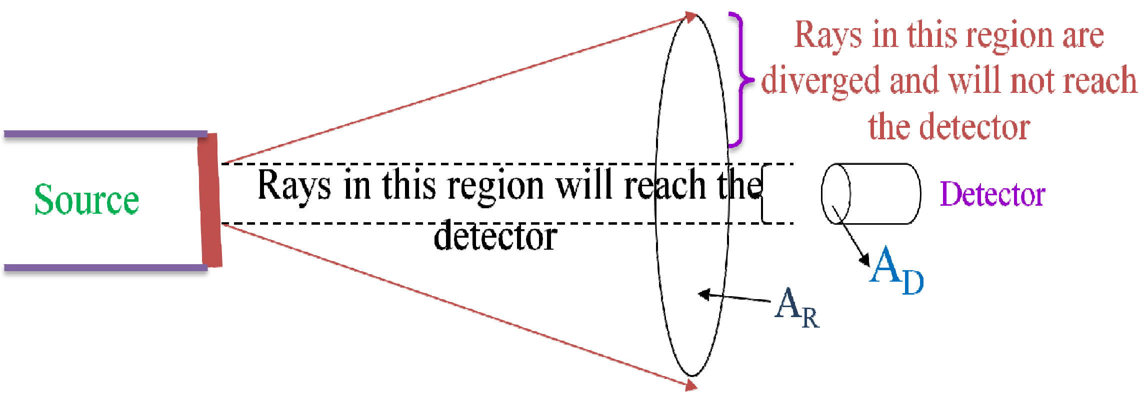


Fig. 5.2: Sketch of divergent rays emitted from a source.

The ratio of the detected radiation is the ratio of the detector area to the tube area which is A_D/A_T=18.49/216.5≅8.5% which is very small. Using this method in experiments with larger targets will be very effective as $A_D/A_R << A_D/A_T$.

Aluminum tube can be considered as a waveguide which is a hollow transmission line in the form of a metal tube. For practical use the wavelengths approaches the cross sectional dimensions of the waveguide. Waveguides are channels of electromagnetic energy as it is a director and a conductor. (http://www.allaboutcircuits.com/vol_2/chpt_14/8.html, 2009). The cross sectional area of the aluminum tube is 216×10^{-6} m^2.

5.4.2. A hemispherical shape reflector:

In Fig.(4.9 b) the dome shaped reflector method is used; in this way the reflector will reflect some of the incident infrared from the other side of the foil as it has a smooth surface; this will increase the detected infrared intensity. At small distances the intensity detected by this method is 13 times the original value, Fig. (5.3) shows the convergence of rays by the hemispherical reflector.

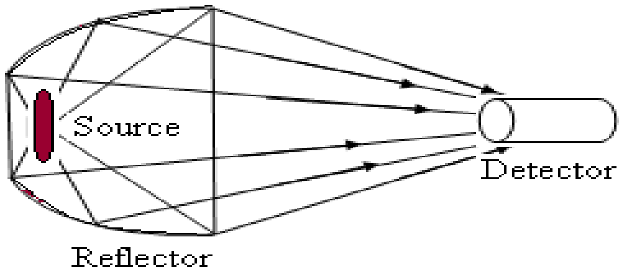


Fig. 5.3: Converging rays from IR source by a hemispherical reflector.

5.4.3. Honey comb mesh shape:

Fig. (4.9 c) shows the effect of using Honey comb mesh shape; it is clear that the method is promising as an inexpensive reflector; intensity at small distances could be 8 times greater than the original intensity. Each hole can be considered as a small collecting tube which will collect infrared to get larger number of converged infrared beams which means larger intensity. The idea behind using simple tubes or Honey comb mesh is to employ useful inexpensive ideas in infrared spectroscopy. IR sources could be designed for extremely low cost; also collimating the beam and could be at very low cost.

5.4.4. Reflective mirror:

A laser mirror was also used as a reflector to collect infrared radiation; Fig. (4.9 d) shows the effect of using it on intensity versus distance. At small distances this method could double the original intensity; it's clear that incident infrared from the other side will be completely reflected so that the intensity is almost doubled. Fig.(5.4) indicates the reflected rays by the mirror.

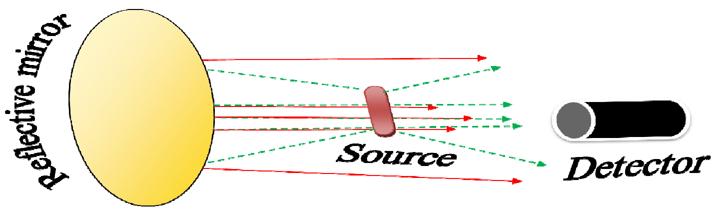


Fig. 5.4: Reflected rays by a reflective mirror.

It is surprising that methods such as guiding tube or Honey mesh was more efficient, although the laser mirror is more sophisticated and expensive. Fig. (4.9 e) shows the comparison of all previous methods to the original graph without any effect. Obviously; the four methods used to focus the infrared from the source are good and successful methods which can be used to get better intensity from sources. Intensity increases; this appears from the shift up of the line. For large distances the effect of focusing decreases; because of divergence of infrared. This divergence is less when the mirror was used. The dome shaped reflector effect remains for large distances longer than the tube method; as the reflector has a large radius compared with that of the guiding tube.

5.5 Other infrared miniature sources

To make use of available material for IR generation a Nichrome wire can be as good as simple available and inexpensive source. This source can be improved to be used successfully. To do so; properties of this source were studied. It's apparent from Fig. (4.10) that the characteristics of the Nichrome wire, as an infrared source, are the same as the Fecralloy sources, the shape of the curve of Fig. (4.10) is almost the same as the curve drawn for Fecralloy sources; that is the intensity decays with distance. It reached the dull red when the current passing through it is 1.28A. This wire is available, not costing too much and can be used as an infrared source.

5.6 Applications

Simple useful infrared applications were studied for the sake of confirming the successful source construction. These applications can be improved and developed to be used in different types of applications.

5.6.1. Liquid absorption of IR radiation:

Fig.(4.12) shows the characteristics of the transmitted infrared radiation through different types of liquids being absorbed by a paper filter. It's found from the graph that the transmitted intensity which was detected is not the same for all liquids, but depends on the type of liquid used.

More transmitted intensity means less absorbance by the liquid, the chemical structure is the limitation of the absorbed and transmitted infrared radiations. For example the sesame oil has a small viscosity compared to other liquids used; so it will allow radiation to be transmitted easily. This appears clearly from Fig. (4.12); which shows the largest intensity. Black cumin oil has larger viscosity than the sesame oil so its curve is shifted downward, the glycerin has the largest viscosity and this will balk the infrared from going through the paper to the other side where the detector is, hence, the absorbed radiation will be large.

Using liquids will simplify the transmission of the infrared through the paper; those liquids will chink the holes and make the paper softer and automatically simplify the transmission process. Water's infrared absorption found to be high and this was reflected on the transmitted radiation which was low. In fact two effects must be at work, firstly the type of material decide the amount of IR radiation absorbed, hence the level of attenuation.

On the other hand absorption of material by the filter paper will result in more opaque target material in the way of the beam. In this way one can use these types of liquids absorbed by filter paper to get more or less infrared, i.e. IR attenuation. Different types of liquids will be classified by detecting the transmitted infrared radiation through them.

5.6.2. Effect of heat on oil properties:

The frying time of vegetable is very important; since it affects the properties and the chemical structure of the oil and can be harmful for human health. So; it is advised to study the effect of heating time of the oil on its infrared absorption, this was examined in Fig. (4.13); which shows the effect of vegetable oil for certain periods of time. It's clear that the intensity increases with time; that is increasing the time will decrease the absorbed radiation. This can be explained depending on the fact that heating the oil will decrease its viscosity; so that it's easier for infrared to be transmitted through as the spaces between oils molecules will increase. Using the oil for ¼ hour does not affect the transmitted infrared too much; even using the oil for ½ hour has little effect, but using this same oil for ¾ hour has increased the transmitted intensity by a factor of 1.2 from the original transmitted infrared of unused oil. Hence a calibration can be established to act as a guide for the threshold heating time after which oil properties began to change.

Improving this method can be useful in preventing harmful effects of the used oil in food industry by detecting the negotiability of used oil and studying the effect of time needed to use the oil without any hazard.

5.6.3. Dependence of dye of same color but different concentration:

Effect of dye proportion used to paint broadcloth can be studied using the detected transmitted infrared; Fig. (4.14) illustrates the effect of dye ratios on broadcloth, it's clear that as the dye increases the transmitted infrared decreases; molecules of dye will fill in the spaces of the broadcloth; this will obviously decrease the transmitted infrared radiation. Simple application of this sort can act as a guide along the production line to ensure the standard of painting fabrics.

5.6.4. Detection of olive oil adulteration with vegetable oil:

Mixed olive oil with vegetable oil was tested; the effect of this mixture is denoted in Fig. (4.15). Vegetable oil was added to olive oil at ratios of 1:1 up to 10:1. As the ratio of olive oil to vegetable oil increases that is adulteration decreases; relative intensity decreases, as olive oil has more viscosity than other vegetable oils its absorption is higher than that of vegetable oil, this is an acceptable and helpful method to discover of olive oil adulteration and the level of adultery.

5.7 Conclusion

The work was successfully finished although it faced some problems during the work especially in preparing and dealing with infrared sources. Determination of the current passing through the foil to reach infrared emitting threshold was a sensitive point. Alignment of source and detector on the same line was an important part of the experiment. Focusing techniques were variable and their results are amazing somehow. Many applications can be used using those sources; four of them were used in this research.

Chapter six

Conclusion and further work

6.1 Conclusions

This work has dealt with the construction of miniature infrared sources, their characteristics were studied so that to be used in applications with less costing and simple mobility. It was found that those sources have same characteristics but different emitted powers depending on frequencies used and their emitting area. Simple available items such as conducting wires could be used as sources for spectroscopy together with other useful applications. There is plenty of room for development in all aspects of these sources.

Focusing methods are very important depending on the aim of using the source for and level of intensity required, one could use small available objects as guides, the four method used were promising. Miniature sources were successfully used in daily important applications.

6.2 Further work

Infrared sources are improvable and can be constructed easily from simple available materials. It's not a big deal to get an infrared source, Fecralloy foils can be developed in different shapes and sizes, encapsulating these sources will make it easy to handle and greatly increase their time life. Even a small inexpensive filament lamp can be used freely if it is encapsulated. It is suggested that further work is to be done on the possibility of sources encapsulation.

Many applications are needed in our daily life; one can use these sources to develop other applications and create new ones. Sources when encapsulated could be used in various applications even for flammable gas detection.

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المصادر الصغيرة تحت الحمراء لتطبيقات قياس الطيف

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ملخص:

قياس الطيف بالأشعة تحت الحمراء فرع مهم من الفيزياء، يستعمل للعديد من التطبيقات المختلفة والمفيدة. يتحرى العمل الحالي عن امكانية بناء مصادر صغيرة للأشعة تحت الحمراء من المواد المتوفرة بسهولة وتفحص خصائص هذه المصادر وامكانية استعمالها في تطبيقات قياس الطيف. هذه المصادر تم تشكيلها من صفيحة (Fecralloy) للحصول على مصادر مشعة ذات وجهين من الأطوال والأعراض المختلفة، وتم دراسة خصائص هذه المصادر عن طريق بناء تجربة بسيطة للحصول على مثل هذه الأشعة تحت الحمراء من المصادر النابضة ولتحقيق التبريد الذاتي لتلك المصادر. تمت دراسة مصدر آخر للأشعة تحت الحمراء ومقارنته مع المصادر المكونة من صفيحة ال (Fecralloy) وهو سلك نيكروم تم تصميمه على شكل لولب. ومن الملاحظ ان هذا المصدر قد صمم من مواد بسيطة وغير مكلفة ومتوافرة حيث يمكن استخدامها بسهولة للحصول على مصادر للأشعة تحت الحمراء واستخدامها في عدة تطبيقات عملية.

بما أن القوة الاشعاعية لمصادر الأشعة تحت الحمراء ضعيفة فإن من الحكمة استخدام طرق لتركيز هذه الأشعة؛ لذلك تم توظيف طرق متعددة من مواد متوفرة وبسيطة وغير مكلفة واستخدامها لتجميع الأشعة تحت الحمراء، ومن هذه الطرق: استخدام انبوب مغلف من الداخل بورقة الومنيوم، وعاكس على شكل نصف كرة، اضافة الى استخدام مرآة لعكس الأشعة. هذه الطرق أعطت نتائج جيدة وخاصة عند استخدام الأنبوب للمسافات القريبة، وما تم ملاحظته أن المرآة من أقل الطرق فعالية على الرغم من أنها أكثر حساسية في الاستخدام وأكثر كلفة.

في نهاية هذا البحث تم استخدام احد المصادرالمشكلة من صفيحة ال (Fecralloy) في بعض التطبيقات المفيدة والتي يمكن تعديلها وتطويرها للاستفادة من الأشعة تحت الحمراء، ومن هذه التطبيقات: دراسة أثرمدة تسخين الزيت على خصائصه، ومقارنة لبعض السوائل عن طريق مقارنة امتصاصها للأشعة تحت الحمراء، ودراسة نسبة خلط زيت الزيتون بزيت نباتي.