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Broadband Infrared Tissue Absorption using Miniature Homemade Infrared Light Source: Preliminary study for Tumor Heating

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Abstract- Infrared tissue absorption spectroscopy is an important tool for both medical diagnosis and treatment purposes. In this work we report broadband infrared tissue absorption using homemade miniature IR source. The usefulness of the miniature IR source is that it can be manufactured in different shapes and sizes that makes it fit for in-vivo studies in small human body cavities. Tissue samples were subjected to a broad infrared band radiation in the range 1-15 μm. The depth of absorption in tissue was monitored to determine efficacy for future use for both diagnosis and treatment purposes. Finding new ways that are characterized as a noninvasive technique, with least or no side effects, low cost and relatively with quick results in cancer diagnosis and treatment. Increasing the temperature of a cancer cell (rat tissue and cancerous cell line) up to ~ 42ºC will give clear indication of new technique to kill cancer cells. Knowing the temperature distribution over the samples radiated by IR radiation allows the possibility to diagnose different cancer cell samples from their heat absorption. This depends on the content absorbing chromospheres of the tissue at the intended wavelengths. Specifying these properties of a tissue is the first step toward choosing proper IR source for the planned therapeutic method.

Key Words: IR source, Tissue absorption, IR Spectroscopy, IR diagnosis and treatment.

1. INTRODUCTION

Tissue absorption spectroscopy is an important tool for both diagnostic and treatment purposes. The particular region of the spectrum Near infrared (NIR) absorption spectroscopy is as old as the seventies of the previous century. It was used for monitoring oxygenation of different body parts [1-2], or the glucose ratio as related to scattering [3] and for optical mammography [4]. Diffuse reflectance and transmission spectroscopy [5] was used to determine fat absorption coefficients which allow the determination of the concentration of key tissue constituents and as well for neuroimaging [6]. The NIR region of the spectrum has set of properties that make it useful for studies of photon penetration dependence, optical diagnosis [7] and both organic and inorganic fluorescence contrast agents [8]. Their unique properties allow designs that can provide simultaneous imaging and photo thermal therapy [9-10]. Many authors show that skin and mucous are the most important tissues for photodynamic therapy of cancer [11-13].

Data specifying optical properties of tissues can be found [14]. The knowledge of tissue absorption and scattering properties cannot be generalized but rather taken as a guide, since tissue content of chromospheres is different from sample to sample. If the intention is therapeutic then maximum tissue absorption is appreciated using collective broadband absorption. An important parameter to consider is the region of IR radiation of highest energy and tissue content of absorbing chromospheres at the intended wavelengths. Specifying these properties of a tissue is the first step toward choosing proper IR source for the planned therapeutic method. Infrared radiation spectrum is divided into three regions: near, mid and far-infrared as related to the visible spectrum. The boundaries between the three regions are not exact and can vary i.e., depending on convention and detector technology used for gathering the radiation. As far as the corresponding energy of each region is concerned it can be said that the region with higher energy is the near-IR, ~ 14000–4000 cm−1 (0.8–2.5 μm), it can excite overtones or harmonic vibrations. The mid-infrared, expands over the range ~ 4000–400 cm−1 (2.5–25 μm) this is suitable to study the fundamental vibrations and corresponding rotational-vibrational structures. The far-infrared region, ~ 400–10 cm−1 (25–1000 μm), has the lowest energy and can be used to excite the rotational modes.

The present study investigates the possibility to use homemade, low cost, miniature IR source for absorption study by biological tissues. Managing to increase the temperature of biological samples (for example, a rat tissue and cancerous cell line) up to ~ 42ºC will give clear indication of new technique to kill cancer cells. More over study the temperature distribution over the samples radiated by IR radiation allows the possibility to diagnose different cancer cell samples from their heat absorption.

Demanding need to find new ways that are characterized as a noninvasive technique, with least or no side effects, low cost and relatively with quick results in cancer diagnosis and treatment attracted many researchers in the last two decades to look for new methods.

In the present work, broadband tissue absorption [15] will be studied using a homemade miniature IR source [16] expected to emit in the range 1-15 μm. The aim of the study is to unveil the possibility of heating a sample by IR radiation for

the sake of tumor treatment by heating. It is advantageous to use homemade, low cost, miniature IR source for absorption study by biological tissues. Study the effect of increasing the temperature on biological samples (rat tissue and cancerous cell line) up to ~ 42ºC and hence allows the temperature distribution over the samples radiated by IR radiation. The possibility to diagnose different cancer cell samples from their heat absorption is then made possible. Light matter interaction are due to absorption and or excitation [17]. The interaction depends on the building blocks of the matter and the wave length of the incident wave which may results in (reflection, refraction or absorption partially or totally of the incident wave … etc.) [18]. Of course not all frequencies of the infrared spectrum are absorbed by the sample.

Lepock (2003) [19] clarify some of the effect of hyperthermia on mammalian cells after exposure to temperature 40-41 ^{0}C the cell growth decreases, the signal pathways changes, it will become more sensitive to other stresses and acquiring thermo tolerance. Exposing for more temperature up to 45 ^{0}C will extensively cause denaturation (process by which the molecular structure of a protein is modified). Also it was showed [20] that the growth of different cancer cell line e.g. (T98G, U87MG, DU145, PC3, H1299, and MCF7) incubated at 40^{0}C was regressed compared to those incubated at 37^{0}C. The temperature of a sectioned porcine skin raised from 26_40 ^{0}C during low level laser therapy (LLLT) [21], the beam characteristics were 1064 nm, 3.14 W/cm^2. Other experiments were done to investigate LLLT thermal effect. A 915 nm, laser was used with different powers and durations 3W for 3min, 3W for 5min, 3W for 7min, 4W for 3min, ….., 5W for 7min, irradiated a KP4 and MIA-PaCa2 cell line (pancreatic cancer cells), the samples were cultured in 96-well plates and incubated at 25ºC. As the power and duration increases the percentage of apoptosis increases. The temperature of the cell media increased almost 11ºC only, Obayashi et al. [22] claimed in his experiment that neither the power was high nor was the duration enough to raise the media temperature to 42ºC in order to describe the effect of LLLT to be thermally accepted. Two modes of action can be used, either radiation can be continuous or pulsed. The monitored effects are either absorption or scattering of the electromagnetic radiation. Electromagnetic pulses revealed much information about the tissue optical properties [23]. Pulsed radiation (PW) is known to penetrate much more than continuous radiation (CW) [24].

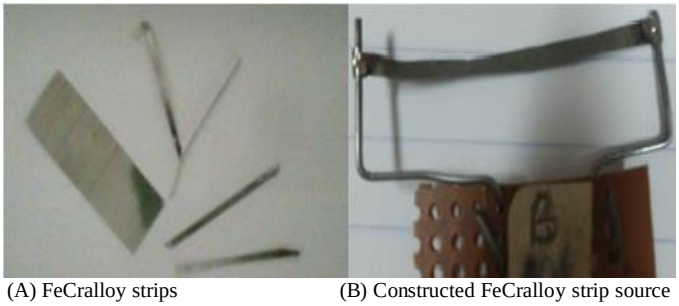
Cancer diagnosis using heat and IR radiation depending on heat penetration employing photoacoustic imaging was reported [23] to detect a 5 cm blood object. Fourier transform infrared (FTIR) is a powerful analytical tool was used by [25] to distinguish between normal and cancer gastric tissue samples. results suggested that the normal samples were more absorbance than cancerous tissue.

IR Sources used in the study can be made locally at the local lab and can take different forms. Full details of such IR sources studied and characterized by Abu-Taha et. al. [16], in this work two source forms used: The spiral shape and the simple flat sheet forms. The IR spiral shape [2] is a fecralloy filament source of 2 mm diameter mounted in a ceramic holder. The emitted pulsed wideband radiation in the region of interest is in the range 0.7 - 15 μm. The source was driven by a current source of 0.2A from a stabilized power function generator. The sheet type source consumes higher currents. The optimum temperature for the experiment was ~ 900 ℃, or when filament is heated to dull red, the melting point of the alloy is ~1380 ℃.

The bispiral coil has a diameter of the order 2 mm and it emits broadband radiation in the range 0.75 - 15 micrometer, when operated at dull red ~ 900 degrees centigrade [26].

Two pulse sources were used in the experiment; a Bispiaral (Fig.1) and FeCr alloy strips source (Fig2 A&B).

Fig. 1: Photo of a bispiral source



(A) FeCralloy strips (B) Constructed FeCralloy strip source

Fig. 2: FeCr alloy sheet and the Homemade Source

The second type IR sources were constructed mainly using a sheet of FeCralloy (Fig2A). This alloy is composed of Fe-Cr-Al steel containing "yttrium" at the following percentages:(Fe72.8/Cr22/Al 5/Y0.1/Zr 0.1) with foil thickness 25 μm. The most versatile of the alloys that is suitable for use over wide range temperatures up to 1300℃. The "yttrium" Y can be used up to (0.3%) is the key to its longer high temperature life, having greater oxidation resistance. The optimum temperature for our experiment was ~ 900 ℃, or when filament is heated to dull red color, the melting point of the alloy is ~1380 ℃. Foils are electrically heated followed by self-cooling process, in order to use them correctly to get the infrared radiation; they must be electrically heated to about 900-1000˚C.

In this study a pyroelectric and thermocouple detectors were used; both are thermal detectors operate at room temperature, their detection [21] temperature distribution over the surface of a porcine skin and at different depths from it is thigh measured after 24 hours of postmortem. The samples were exposed to a CW radiation of wavelength of 1064 nm and intensity equals 3.14 W/cm^2. The surface temperature was increased from 26^{0}C to 40^{0}C, and observed by an Infrared

Camera, at depths of 0.1, 0.2, 0.3, 0.4, and 0.5 cm and each one temperature was measured by T-thermocouple and they were respectively; 38, 34, 31, 30, and 29^{0}C. According to Kim and Jeong [21], no thermal damage was observed below 40^{0}C. Similarly, was done by [29] experiment when two groups of black and white mice were exposed to CW laser 830 nm in order to examine the effective heat for biological tissue, each group contained 12 mice. In black group the surface temperature was reported to increase by4.44 ^{0}C after receiving 5 Joules, the surface initial temperature was 29^{0}C±1^{0}C monitored using a thermal camera and two other thermocouples were localized, at 1mm depth the measured increment temperature was 3.21^{0}C from an initial of 31^{0}C ± 1.3^{0}C while the temperature increment was lower in the white group. The difference between [29] and [21] experiments results was because [29] experiment was done in vivo while Kim and Jeong [21] experiment was done in vitro, this supports the idea of living tissue differs from postmortem one [30]. The absorbed broadband infrared radiation from a homemade source will produce thermal effect in the biological samples and some cancer cell line. Any change in the heat inside the tissue will cause a temperature change [31] and so, temperature was measured by thermocouple to record the change that the source could influence the samples; since temperature change can be an indication for the samples conditions. Luk, Hulse, and Phillips (1980) [32], conducted a review of literature extended for more than 100 years and concluded that many scientists whom combined hyperthermia to surgical or radiation cancer treatment found positive effect on patient's health. Hyperthermia experiments showed that positive influence of heat in treatment; the researchers heated tumor cells and anti-tumor effect for cells using a water bath risen the temperature samples to 42 ^{0}C for 30 minutes, by comparing the growth of treated tumor cells with untreated one it was clear from the experimental results that after 10 days of growth the treated cancer cells mean diameter (mm) was decreased and left up the killer cells ability in the used model.

It is known that cancer is a disease in which cells grow and divide uncontrollable. Medicine researchers always look for alternative treatments that avoid harm to normal tissue [32]. The side effects of the traditional treatments for cancer motivated researchers toward low-energy IR radiation treatment [33]. Thermal therapies are a promising alternative treatment [34] and this is because high temperature can damage and kill cancer cells, usually with minimal injury to normal tissues ([32], [35]).

Hyperthermia is almost always used with other forms of cancer therapy, such as radiation therapy and chemotherapy. It may make some cancer cells more sensitive to radiation or harm other cancer cells that radiation cannot damage. When hyperthermia and radiation therapy are combined, they are often given within an hour of each other. Hyperthermia can also enhance the effects of certain anticancer. The effectiveness of hyperthermia treatment is related to the temperature achieved during the treatment, as well as the length of treatment and cell and tissue characteristics [32, 35, 37, 38].

Some cancer diseases are difficult to be diagnosed at early stages of the disease e.g. gastric cancer [39]. Finding new methods to detect cancerous tissues makes infrared method a reality, due to huge clinical studies and development of infrared spectroscopy instruments. This method is non-destructive for biological samples compared to ultraviolet, x-rays and gamma rays [40-41]. It has the ability to distinguish between normal and tumor tissue, since tumor tissues absorbs more Infrared radiation than healthy one, this can be displaced by photograph using Infrared cameras. It is important to find new novel technique to diagnose the disease in its earlier stages similar to "biochemical finger print" of the tissue [25], in most cases by the time of tumor detection, it would be widely spread in the body [22].

Cancer Cells affected by heat, i.e. hyperthermia mechanisms are not well known yet, but there are some indications such as protein denaturation and DNA damaging by radiation causes growth stop [19] also, changes in the membrane permeability and distortion in the cell shape is sustained. Temperature above 41^{0}C is a toxic temperature for cancer cells [20], and is used for growth suppression. Cancer cells are affected by radiation faster than normal cells because their cells tend to divide more quickly and they grew out of control. Their sensitivity to heat because they cannot adapt themselves with physiological stresses of heat and this make them more susceptive to heat-induced death than normal cells due to damaging proteins and structures within cells [42]. Of course if the absorbed heat by tissue was large enough, it causes burns or tissue damage [43].

2. EXPERIMENATL SYSTEM

Using Fe-Cr-Y source which was powered by an electrical circuit [27]. In this work a broad band infrared radiation will be allowed to fall on biological samples and to achieve this goal several steps were taken to ensure the results reliability. The source is attached to an electrically pulsed circuit. This allows it to radiate pulsed broad band infrared radiation. The complete experimental circuit used to run the IR source is shown in Fig. 3.

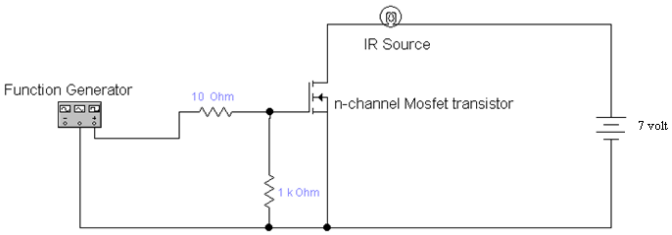


Fig. 3: Schematic showing rurning circuit of the constructed Fe-Cr-Y source.

White rats were used in order to study the temperature distribution over the belly shaved skin and at 1mm depth of skin; which is the rat's skin thickness. Also, the belly upper muscle was examined and its thigh temperature depth. These areas were marked and temperature was taken for these spots using a thermocouple.

Cancer cell lines were cultured in a 10cm cell culture dish and incubated in humidity chamber at 37°C with 5% CO2. First stage was measuring temperature for cancer cell line at

marked points within 10minutes duration in an open hood out from the incubator. Thermocouple type k was used to measure temperature.

Fig. 4: Photo showing experimental setup for in VIVO IR tissue absorption.

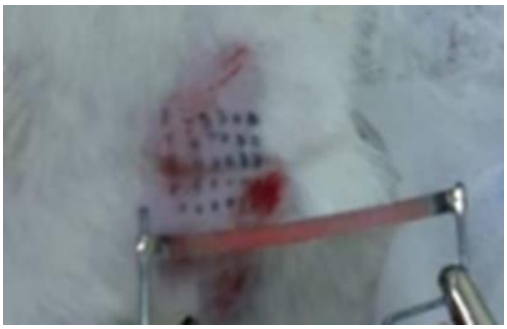


Fig. 5: Photo showing direct IR absorption set up by rat's shaved skin.

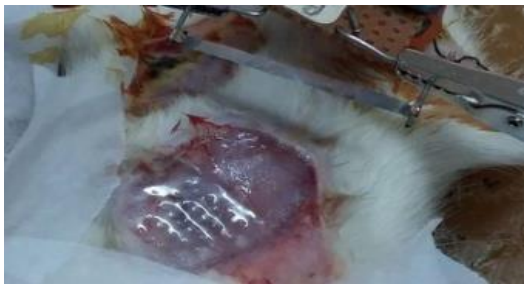


Fig. 6: Photo showing in vivo IR absoprtion set up by rat's belly muscle.

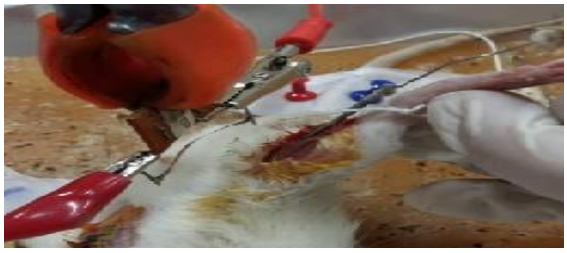


Fig. 7: Photo showing in-vivo IR absorption set up at different depths in thigh tissue.

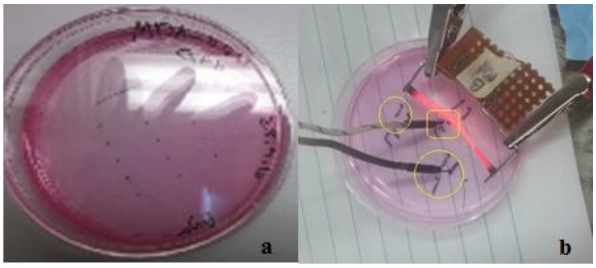


Fig. 8: A photo of 10cm cell culture dishmarked in different ways to monitor temperature; a) marked as grid. b) marked as separated area.

Rat tissue temperature investigation by point temperature distribution over an excised white rat tissue, over dead rat tissue (not excised tissue), and for white rat living tissue. The targeted tissue was skin surface, back side of the skin; its thickness is 1 mm, and muscles tissue; belly surface and for different depths of the rat thigh; the muscles are directly exposed to radiation after removing the skin. Six controlled white rats were used, Ketamine was used to anesthetize a 174.3 gm white rat; one mg of Ketamine was dissolved in 10 mg of saline and was given to the rat by injecting it under the skin in the abdomen area. It is useful for short procedures and is inexpensive [44], the rest of them were death using formalin and ethanol. The electrical arrangements for Fe-Cr-Y source were almost the same for all experiments and they were: 12 Hz frequency and voltage ranged from 5.00 to 6.00 volts and the current oscillated between (2.21-2.70) Ampere. While the electrical arrangements for Bi-spiral source were: current 0.3 Ampere, AC voltage 1.69 volts and frequency was 12 Hz.

Cancer cell line that keep dividing and growing over time. They are used in research to study the biology of cancer and to test cancer treatments. For example, breast cancer cell lines include MCF7, MDA cells were grown in RPMI media from tissue culture lab. The sample was exposed to the IR radiation to investigate the influence of radiation on the cell proliferation.

Some trials were done in tissue culture lab, where irradiation sessions were done in an open hood. The source placed ≈ 2.00 cm away from the sample and the electrical arrangements of the experiments were: frequency 13 Hz, voltage ranged between 4.90 to 6.80 volts and current oscillated between 2.31 and 2.51 Ampere.

3. RESULTS AND DISCUSSION

In-vitro and in vivo trials of rat samples were studied, sectioned pieces of white rat tissues were irradiated by Fe-Cr-Y source to study temperature distribution. Results are listed below, different trial is accompanied with certain condition. Samples taken for vitro trial are spread over a plexiglass plate. Strength of tissue temperature change depends on the presence of chromophores (molecules in a given material that absorb particular wavelengths) [45, 46, 50] in the tissue structure. It was noticed that as life metabolism becomes less absorption of IR also becomes less. The experimental arrangement is shown in Fig. 9; a gold reflector is used to increase amount of radiation from the source on the target.

Fig. 9: A photo of the experimental in vivo set up using gold coated mirror for increased back irradiation.

A contour plotting for temperature distribution over the horizontal area of the shaved skinned sample was performed. Only measured temperature was for the above area of the IR source, see Fig. 10.

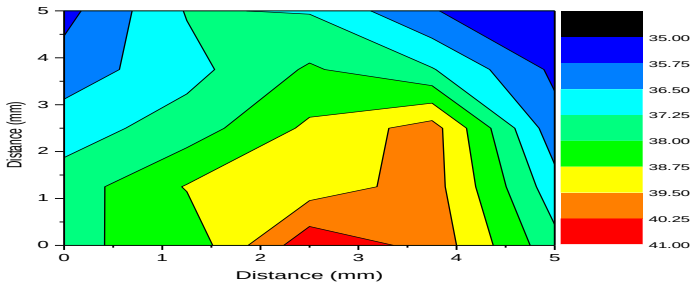


Fig. 10: Contour temperature distribution over upper part of skin tissue (in vitro), the vertical, right scale gives temp in degrees.

The IR heat is focused under the source directly and decreases as the distance from the source become farther, these results agree with Kengne and co-workers [36] concerning the behavior of bio-heat transfer through tissue based on their model which is nonlinear bio-heat equation of Penne's type. Despite the cessation of blood circulation in the rat's dead body the temperature increased from 30^0C to almost 41^0C which means that there are still some mechanisms working within an hour of animal death.

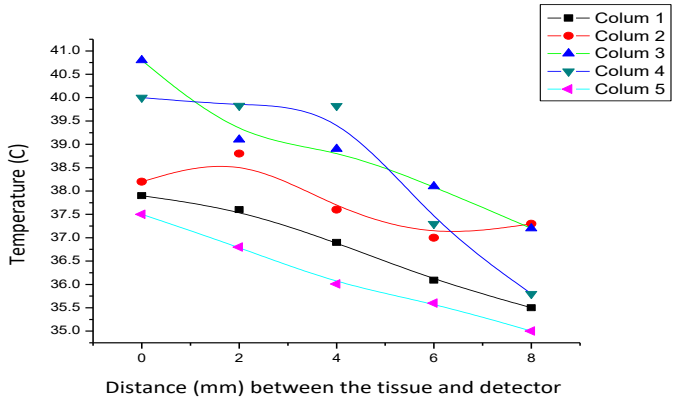


Fig. 11: Measured temperature versus distance (in vitro results)

Relationship of temperature-distance for biological tissue cannot be described as linear [36] or by an exponential decay relation [46], but mainly dependent on the availability of chromophores and skin color [29].

Whole and excised rat body irradiated at specific area by Bi-spiral and Fe-Cr-Y source**,** a dead white rat weighted 373.0 gm was used, the session started 16.00 minutes after the death, its temperature before irradiation was 28ºC. The Bi-spiral source was fixed from the target sample by 1.70 cm using the usual electrical arrangements, Fig.13 bellow show the source IR intensity versus distance fitting. The environment temperature was 18ºC. The irradiated area estimated in the range 2×2 points which equals 5 mm^2 it was marked after shaving the upper part of rat skin in belly area. The session duration was 17.00 minutes and each temperature reading duration was 40 second.

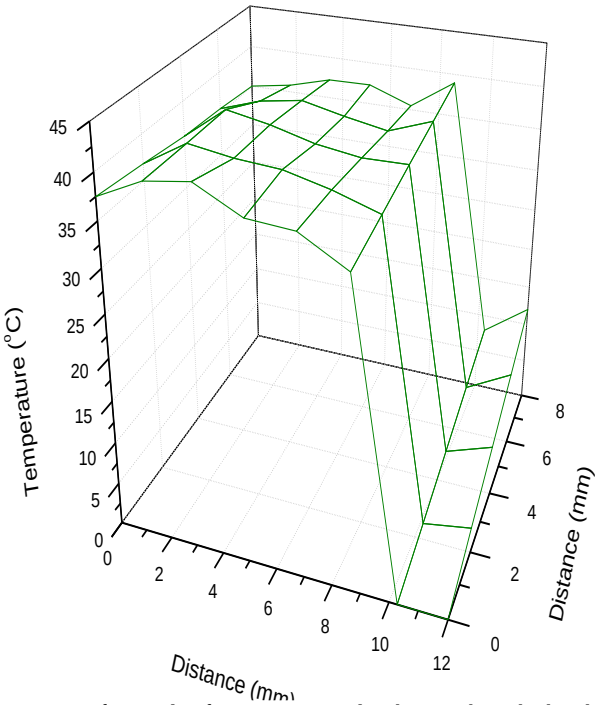


Fig. 12: Wire frame plot for temperature distribution through the shaved marked skin (in-vitro).

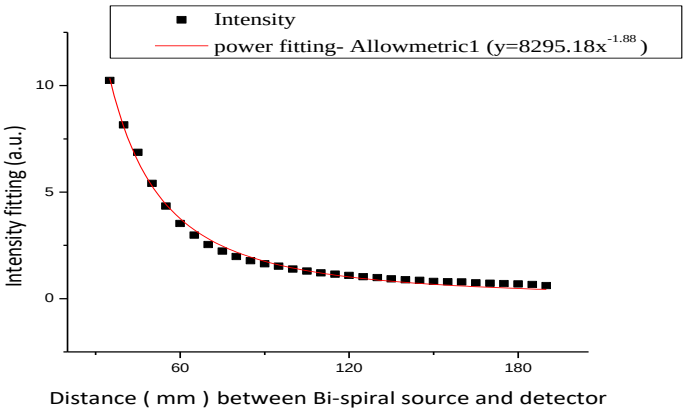


Fig. 13: IR Intensity vs. distance fitting for bispiral source

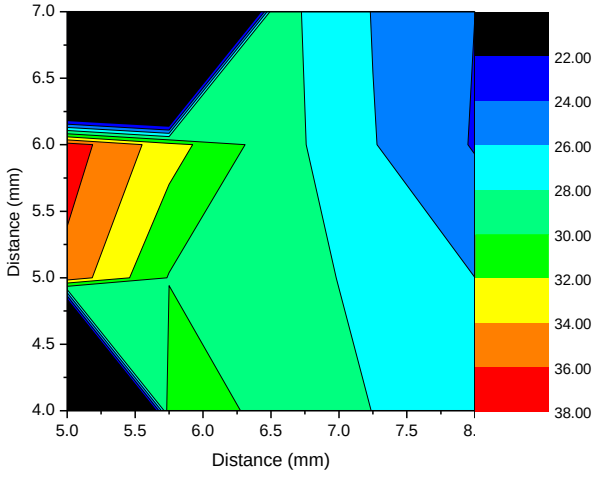


Fig. 14: Temperature distribution over inner side of skin tissue (in vitro) using Fe-Cr-Y source, Vertical scale in degrees centigrade.

Part of skin irradiated using Fe-Cr-Y source. Untreated skin tissue was sectioned and kept into ice for one hour and 40.00 minutes. Each duration reading was 40 second. The temperature of the tissue before radiation was 21ºC. A contour plot of temperature distribution over the inner side of white skinned rat is shown in Fig. 14.

The thermocouple probe was placed under the Fe-Cr-Y source directly; measured tissue temperature at the end of session was 38ºC, session duration was 14.00 minutes. It seems that as the time of death passes the ability of the sample to absorb heat is weaker than living tissue; because thermoregulation in the tissue is not active any more [29]. Temperature increase from 22ºC to more than 42ºC for only 1.66 min for the muscle surface while at 3.64 mm depth temperature increase from 22ºC to more than 37ºC; this means the ability of IR broadband to affect tissue at depth greater than 3 mm of skeletal muscle [24, 30].

In-vivo trial using rat sample: the white rat weight 174.3 gm, its temperature after anesthesia was 31ºC, and the environment temperature was 35ºC.

Upper part of skin, each point's temperature duration was 39.0 second for most of them; the total session time was 11.77 minutes. The measurement pattern was taken horizontally raw by raw marked over its shaved skin. Results are summarized in table 8 and plotted, see Fig. 15.

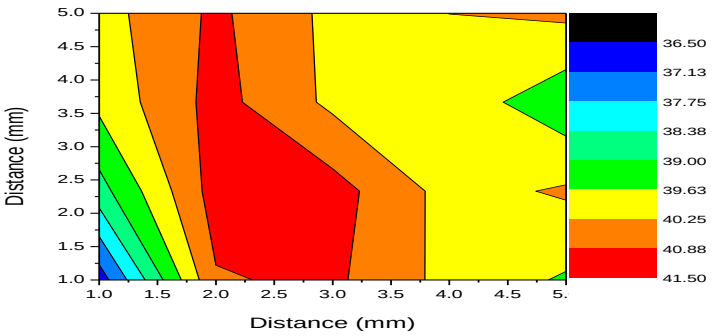


Fig. 15: Temperature distribution over upper part of skin tissue for the first 11 minutes (in vivo).

Temperature-distance was plotted for each raw, Fig. 16.

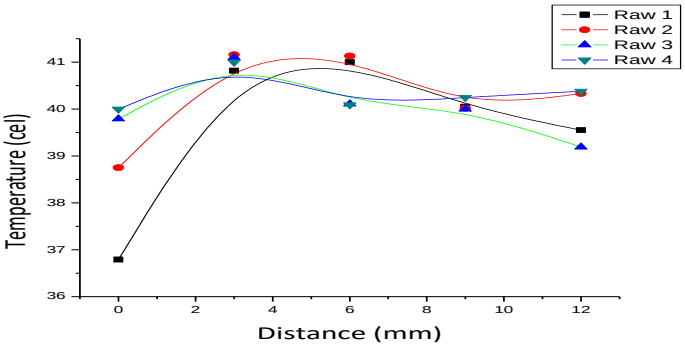


Fig. 16: Measured temperature versus distance (in vivo) for 11.77 min session duration

As mentioned before the relationship is non-linear; since the metabolism in living tissue is temperature dependent [36]. The interactions of each tissue with radiation is unique in its structure [18].

In Stadler et. al. experiment [28] in vitro temperature results recorded has higher values than in vivo temperature results after irradiating the targets with 5 J/cm^2 in Low level laser therapy session (LLLT), but this is not the case in this experiments; the results for (Whole rat body irradiated at specific area by Fe-Cr-Y source), the highest temperature recorded after 33.00 minutes of white skinned rat was 41 ºC while in vivo trial for upper shaved skin of white rat after only 11.77 min was 41ºC and this contradicts Stadler et. al [29] results.

After 11.77 minutes of radiation, the same points were followed after the first session duration. Temperature read duration range was (15.5-30.0) second. The session duration was 7.21 minutes. The contour plot representing temperature distribution, see Fig. 17. The temperature reading was taken in a column pattern.

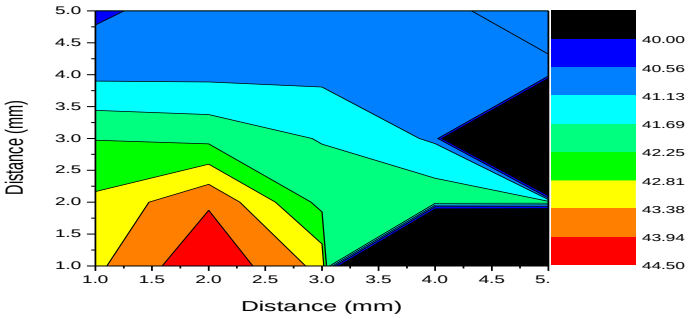


Fig. 17: Temperature distribution over upper part of skin tissue after 11.77 minutes from irradiation (in vivo).

The results were plotted column by column to investigate temperature-distance distribution, Fig.18.

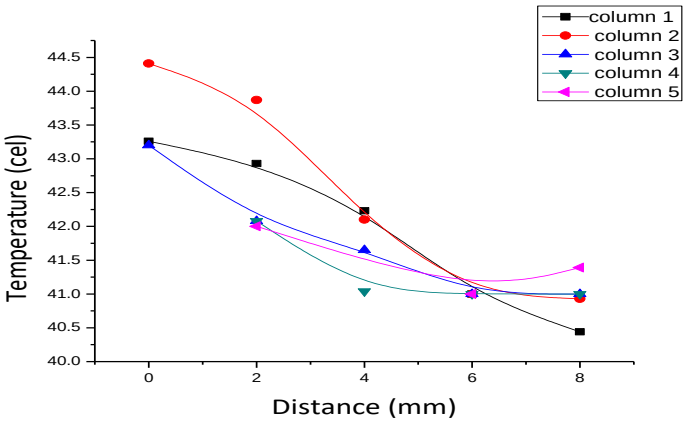


Fig. 18: Measured temperature versus distance (in vivo) after 11.77 min of radiation

Abdomen muscle, Temperature duration of each point marked over the abdomen muscle ranged between 60.5sec and 47.7 sec completing a session of 14.51 minutes; the duration was longer from previous because muscles have less chromophores. A contour plot for temperature distribution is represented in Fig. 19.

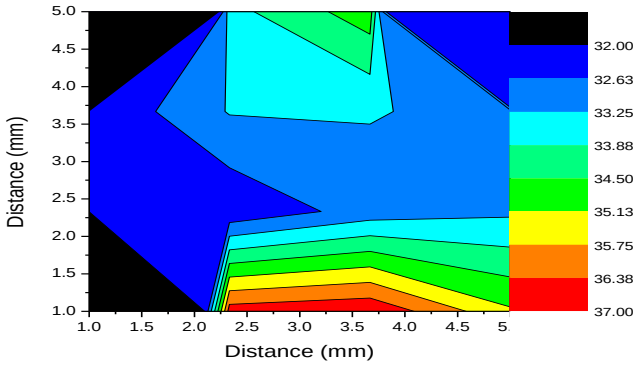
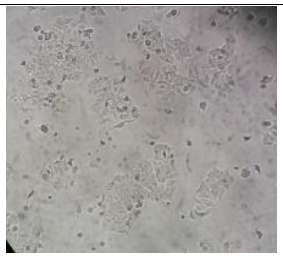
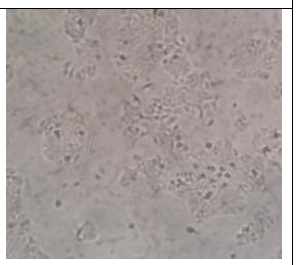
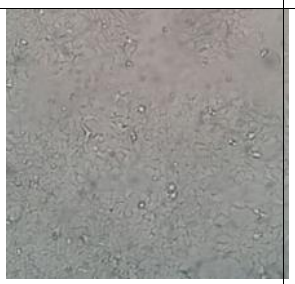
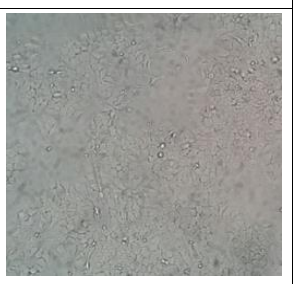


Fig. 19: Temperature distribution over abdomen muscle

At the end of the session; after 10.79 minutes the maximum recorded temperature was 37ºC less than the temperature recorded for the rat skin, but almost the same as the abdomen muscle, this is expected since the muscles contain less chromophores.

Cancer cell line samples study using Fe-Cr-Y source radiation was directed to cancer cell which caused a temperature increase in the sample media. To eliminate any chance that heat affected the media and changed its properties; a small experiment was done; an amount of RPMI (culture media) was exposed to Fe-Cr-Y source radiation for two days, each session was two hours, then it was used to grow a breast cancer sample name T-47D which was splitted into two plates one of them was used as a control which was grown in an untreated media and the other one was grown in the treated media. After 48 hrs of observations the results reveal any effect of heat on the media, table1.

Table 1: Following up the development of culturing cancer cell line T-47D in treated media with IR irradiation

	Control plate	Treated plate
3^{d} day of being cultured		
6th day of being cultured		

First stage results, a group of cancer cell samples were examined out of the incubator environment in an open hood.

MCF-7 cell line, on cultured plates specific areas were marked (position (P) 1, 2 and 3) in order to be monitored see Fig. 20. Ten trials were done and each duration trial was ≅ 3.00 minutes for all readings and in between these trials the plate was returned back to the incubator for couple of minutes.

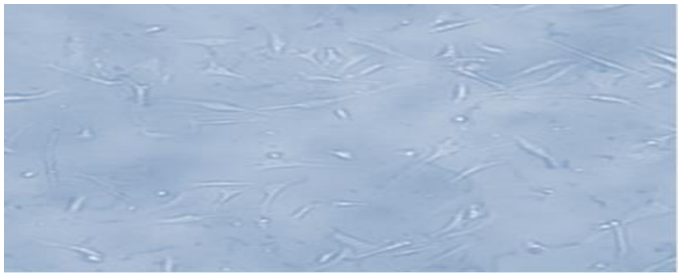


Fig. 20: a photo of untreated MDA cell line

Fig. 21: Marked 10cm cell culture dish placed under a flat strip IR source

The results are summarized:

1. The average temperature of P.1 was 32.75ºC after 47:14 min.
2. The temperature of the lower area of P.2 was 43.75ºC after 29:28 min.
3. The temperature of the upper area of P.3 was 49.84ºC after 47:14 min.

<u>After 24 hours the session was repeated.</u>

The temperature of the sample before radiation was 26.09ºC.

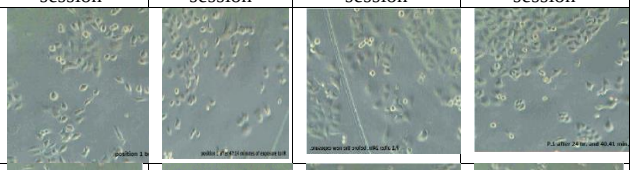
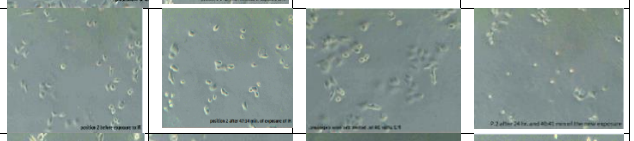
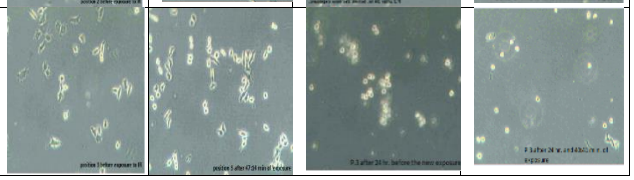
The results are summarized:

1. The average temperature of P.1 was 28.42ºC for 28 min.
2. The temperature of the upper area of P.3 was 42ºC after 3 minutes.
3. The first 18 min. P.2 was exposed directly to irradiation; its average temperature was only 38.45ºC.
4. P.1 was repositioned after the first 28 min under the source directly for the next 9:32 min, Photos were taken for different sessions and arranged in table 2.

First irradiation session; position 3 was directly beneath the source; which meant it was the closest one to the source radiation next to it positioned respectively; area 2 and 1; absorbed heat diffused through the sample media in an ascending pattern from position 3 to 1, position 3 temperature was more than 49^{0}C at the end of session 1 (total radiation time was 47:14 min) and according to the taken photos by the inverted microscope there was no effect on the cell line in that area, it needed another 24 hours to show some effects. The breast cancer cells type is epithelial (ATCC, 2017), and epithelial cells have an adhesion dependent for survival [47], the cells were detached to the dish surface because of heat even though; this cannot be an evidence that the cell lines had a biological change on the contrary taken a look for all over the cultured plate indicated a growth in cells and a normal

existence of death cells, it was mostly re-adhesion after while from returning it back to its suitable environment in the incubator and this is an advantage to the cancer cells [47] – [48]. Heating showed that it is a potential technique for inhibition metastasis growth [32]. Cancer cell cultured in vitro in different temperature will go an exponential growth phase after several hours [49], so heating the samples media by IR radiation with small doses cause a cell increase.

Table 2 below, show the changes that were caused by irradiating adenocarcinoma cell line sample with broad band infrared radiation using Fe-Cr-Y source

	Before 1st irradiation session	After 1st irradiation session	After 24 hrs. of 1st irradiation session	After 2nd irradiation session
Position 1				
Position 2				
Position 3				

4. CONCLUSION

This work is an extension to Abu-Taha and co-workers research [16] about Miniature Infrared Sources for Spectroscopy Applications where the electrical circuit that is running the source is reused in this project for medical uses. Also, there is a good possibility of creating different designed sources shapes. The possibility of enhancing the IR radiation source in simple and inexpensive technique was studied; an aluminum waveguide tube, together with a hemispherical reflector and plane coated mirror were used in the study; the aluminum guide tube was used to deliver IR radiation efficiently to the wanted direction maintaining high radiation intensity, but in order to benefit from the back side of the source radiation a hemispherical reflector tool is the best choice. Biological samples were used to monitor their temperature during exposing them to IR radiation using Fe-Cr-Y source and Bi-spiral source, in this experiment Fe-Cr-Y source proved its ability to raise the tissue temperature more than the Bi-spiral source as shown in the tables. In vivo biological tissue of white rat's skin, abdomen muscle and thigh muscle chromophores play the main rule in absorption of IR radiation. Temperature distribution over tissue has a non-linear form and its value was greater for living tissue than dead one. IR radiation effect of different cancer cell lines were presented. Different types of cancer cell lines irradiated but with different duration sessions shown suppression in the cell lines proliferation.

In conclusion a simple inexpensive IR source emitting in the range 700-15000 nm proved suitable to raise biological samples temperature. This indicates possible use to thermally kill cancer cells in tissue above 40 ^{0}C in accordance with Kim and Jong [21]. Cancer cells affected by heat, i.e. hyperthermia mechanisms are not well known yet, but there are some indications such as protein denaturation and DNA damaging by radiation causes growth stop [19] also, changes in the membrane permeability and distortion in the cell shape is sustained. According to [20], temperature above 41^{0}C is a toxic temperature for cancer cells and is used for growth suppression. Cancer cells are affected by radiation faster than normal cells because their cells tend to divide more quickly and they grew out of control. Despite the cessation of blood circulation in the rat's dead body the temperature increased from 30^{0}C to almost 41^{0}C which means that there are still some mechanisms working within an hour of the animal death.

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