High intensity infrared radiation system for medical application

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According to the geometry optical principles, a high intensity infrared radiation system for medical application is designed. In this system, the infrared optical fiber's output energy density can reach 17 kW/cm^2 after being focused, and the diameter of the focus light spot is 0.3 mm. Thus, the system can be widely used in different kinds of medical applications.

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The high intensity infrared radiation system for medical application has been widely used around the world. The system is popular in gynaecology, dermatology, stomatology, and cancer treatment when the pathological position can be easily irradiated. Its small size and dependable performance make it suitable for the clinics, wards and out patient. Especially it is good for the basic level hospitals and medical clinics in the counties. The main function of this system is to stop bleeding, coagulation and sterilization. In the current market, the specifications of this device are 150- and 250-W light sources, and the output infrared radiation power is only 15–20 W and 20–30 W respectively. The drawbacks of the current device are 1) low utilization of light energy, large amount of light energy is wasted and only 5%–10% is used in the medical practice; 2) Unreasonable design of the light collector, most light cannot be conducted; 3) thick quartz stick (ϕ 9.0 mm) for transmitting light energy. These result in low density of the light power and big irradiation area, which make it impossible to implement a lot of medical practice and cause a big loss of the light energy.

This article redesigned the above medical system according to the geometry optical principles[1]. Because this wavelength of light has a good penetration at the epidermis, demis and subcutaneous tissue of the human body, which means it can enter at a depth of 20–30 mm. When irradiating the human body with 0.6–3.0 μm radiation, the heating and physiotherapy can be implemented at a certain depth. We hope to develop a light source device, which can generate 0.3–3.5 μm strong infrared radiation (including visible radiation). This device can collect the light source energy in the most effective way. When the light energy density increases to a certain degree, burn, sterilization, coagulation and other preferred medical functions will be activated. We believe it will be a popular device in the clinics.

The light source is the core component of this design. The article will discuss how to lower the cost and simplify the structure based on the focus characteristics of the light source.

Firstly, choose the light source material. We should consider its availability, convenience and cost. Currently, most infrared radiation medical system uses halogenide-tungsten lamp[2]. Tungsten has many features, high melting point (3680 K), low evaporation rate, good selectivity in the visible radiation range, strong mechanical intensity under the high temperature and easy to be fabricated. Tungsten filament lamp is a mostly used irradiation source in the near infrared radiation measurement. However, due to the glass cover restrictions to the infrared irradiation by the glass cover, the irradiation wavelength is less than 3 μm. Put the tungsten filament lamp in a light bulb with full of noble gases and an infrared radiation passing through window, this way the infrared wavelength can be extended. For example, in the process of vacuum extraction, the temperature of the regular lamp can be 1800 °C, while the lamp filled with Argon can be 2700 °C. According to the specified experiment requirement, a light source that can pass through a longer infrared irradiation is needed. Therefore, we change the glass cover to the quartz cover. The quartz cover is more durable and stronger than the glass cover[3]. and can be heated to a higher temperature. The longer wavelength infrared irradiation can be realized.

Secondly, consider the shape of the filament[4]. In order to reduce the outside radiation and implement the self-focus function, we designed a tungsten filament in a shape of a brush in a bundle structure. Put this tungsten filament into a tungsten tube. The radiation works from the principal axis of the tungsten tube to the outside, the large amount of the tungsten filaments will generate a lightening section.

Thirdly, design the outer cover and type. The outlook of the outer cover is shown in Fig. 1. In the front, it is a half convex lens with self-focusing long lampshade. Where, f $(= 5 - -7$ mm) is the front lens' focal length, the diameter of the lamp and the light source surface are the smaller the better, the material is quartz glass (the thickness of the glass is less than 1.0 mm), with good transparency and without glass-line. The length of the lamp is (15 ± 1) mm, the power is between 150 and 250 W.

In order to make the light source form parallel radiation of light at the focus point, and enforce the energy through the lens focusing, we want to design a high reflectivity, low reflection loss and parallel light beam spread out, which is good for the focus of light and light waveguide coupling and transmission.

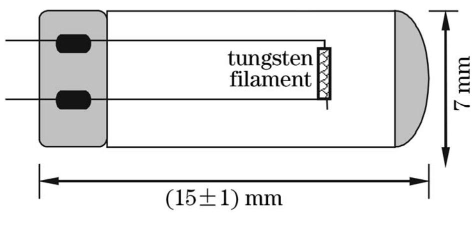

Fig. 1. Self-focus light source design.

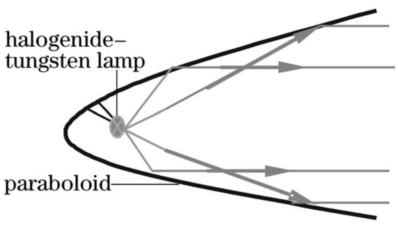

Fig. 2. Paraboloid design.

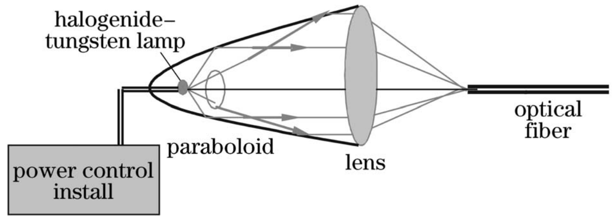

Fig. 3. Illustration of the design of the high intensity infrared radiation medical system.

According to the concave reflection principle, through calculation, we can get the formula $y = \frac{1}{4f}x^2$ (f is the focal length), rotate the curve by the y coordinate, we will get the paraboloid. Thus, based on the requirement of the real device and light source, we decide $f = 5$ mm, then the paraboloid is drawn (Fig. 2).

We can enhance the reflective property by plating on the inner surface of the paraboloid. Then, refocus the parallel radiation of light beams to enhance the light energy. Thus make preparations for the next step, which is coupling the light wave guide. Therefore, we designed a converging lens, such as flat-convex, concave-convex and convex-convex lens. The convex-convex lens can generate the stronger focal energy among them by the experiments result.

Considering that the light radiation forms a circular cone after being focused, and only when the incident angle is less than 45° can the optical fiber conduction start. Furthermore, when the incident angle is 0°, that is the incident light radiation is vertical to the end, the highest coupling efficiency can be reached. Thus we fabricated the incident end as a little trapezoid so that the incident angle is reduced. And according to the different practical applications, we have fabricated optical fibers of different specifications, which constructed an applicable system.

The output mode of the radiation is completed by the different conductive optical fibers with different diameters. The light energy density is increased by over 2 times. Due to the above two points, the output light intensity of the original infrared radiation medical system is increased by 4 times. Thus the light energy intensity of the therapeutic area is increased by many times which meets the medical requirements and improves the economical and social effects. The design of the whole system is shown in Fig. 3.

Through the tests, measurements and analysis, the renovate infrared radiation medical system is greatly improved with respect to the light conduction performance and power. The transmitted energy is increased by over 80%. We use the focal system combining the non-spherical reflecting mirror with convergent lens, and use different diameter conductive optical fiber as the light conduction device, the light source is the 150- and 240-W high temperature halogenide-tungsten lamp. By the controlled power supply, the different continuous operation, different irradiation power switch are implemented. All the strong infrared radiation medical system functionalities are implemented.

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