Light for treating skin diseases

Electrodeless UVB discharge lamp offers an affordable alternative to medical light sources

Narrowband UVB radiation centered at about 308 nm is widely used in dermatology for the treatment of common skin disorders like psoriasis. Light sources used for this kind of phototherapy are excimer lasers and dielectric barrier discharge (DBD) lamps. Electrodeless exciplex lamps are a new approach to obtain a simple, long-living and environment-friendly UVB device that every dermatologist can afford. A first demonstration device has been built within a joint research project. In a clinical test with 20 patients it could be demonstrated that the new lamp is well-suited for hospital use and capable of easing psoriasis significantly.

Psoriasis is a common, chronic skin disease, affecting approximately 2 % of the population in Germany. The costs of psoriasis therapy and additional social costs of the disease are an important issue for the society and the health care system. Narrowband UVB phototherapy is a widely used psoriasis treatment with no need for additional drugs and with only low side effects.

DBD lamps and Eximer Lasers

Commercially available exciplex lamps for narrowband 308 nm phototherapy are driven by dielectric barrier discharges (DBD). These DBD lamps are using at least one insulating layer (the dielectric) in the current path between metal electrodes [1] and achieve an irradiance in the UVB of about 50 mW/cm² for large irradiating areas of up to 500 cm² [2]. Numerous clinical studies demonstrated that DBD exciplex lamps can be applied successfully in dermatology [2]. Furthermore, excimer lasers are used for curing psoriasis. Dermatological 308 nm excimer lasers provide a very narrow emission spectrum and high irradiances in the range of 200 to 500 mW/cm² for small spot sizes of about 5 cm² [3].

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Electrodeless exciplex lamp

The electrodeless UVB exciplex lamp is a novel source type that uses a radio frequency to excite an exciplex forming gas mixture by inductive energy coupling, as illustrated in Figure 1. This new lamp is entirely electrodeless and especially simple. Compared to exciplex devices currently available on the market, its fabrication cost and market price are expected to be clearly lower. The lamp principally avoids electrode corrosion and thus its lifetime is estimated to be in excess of 50,000 hours. Moreover, the working gas of this exciplex UVB source does not contain metal vapors like mercury or cadmium and thus the devices is easy to recycle.

The lamp is working with a binary xenon-chlorine gas mixture and represents a continuously operating XeCl* exciplex device. It is a planar radiator with an inductive radio frequency (RF) gas discharge excitation and a small radiating area of 3 cm². The lamp uses a radio frequency of about 3 MHz to ignite a plasma in a sealed, cylindrical, gas-filled quartz vessel. Besides the xenon-chlorine compound the exciplex forming gas mixture inside the quartz vessel also contains the buffer gas argon. Xenon is the main component of the gas mixture and the chlorine portion amounts to a few percent only. The applied total gas pressure is in the range of 1 mbar. The ratio of the xenon, chlorine and argon components as well as the gas pressure were optimized for achieving maximum irradiance in the UVB spectral range.

The quartz vessel filled with the optimized mixture is mounted in a compact, air-cooled hand piece that also includes the RF coupling spool. This spool is part of a series resonant circuit and holds the gas-filled quartz vessel in its core. Moreover, the radio frequency used for plasma excitation is controlled automatically by a closed loop set-up to ensure that always maximum energy is coupled into the gas mixture. The 100 W transceiver that feeds the hand piece is arranged within a separate housing, including the system for automatic frequency control and the operating unit. A demonstration device of the lamp is depicted in Figure 2.

A 70 mm long quartz rod is joined to the gas-filled quartz vessel, which is shown in Figure 3. Generated exciplex radiation propagating along the axis of the quartz rod passes out of the hand piece via the rod and can be used for the UVB curing process (see Figure 4). Thereby the quartz rod fulfills three tasks. Firstly it ensures an adequately homogeneous irradiance throughout the rod’s exit plane. Further, it absorbs harmful short-wave radiation. Its third purpose is to act as a thermal shield between the hot gas vessel and the patient's skin that directly touches the exit plane of the quartz rod during treatment.

Characteristics of the lamp emission

The lamp emits an almost monochromatic spectrum just like an excimer laser, but the emission is incoherent and nondirectional. However, coherent and directed UV radiation is not necessary for medical phototherapy. The spectral irradiance at the exit plane of the quartz rod is depicted in Figure 5. The spectral irradiance reaches its maximum at 307 nm and shows a bandwidth (FWHM) of 7 nm. 78 % of the measured total power per square meter is attributed to the UVB wavelength range. The rest is UVC radiation (9 %), UVA radiation (10 %) and visible light (3 %). The emission in the Vacuum UV spectral range is negligible and far below a threshold value that is harmful for human skin during a phototherapy. 55 % of the radiant power is within the medically exceedingly effective wavelength range from 300 to 315 nm. This spectral region is also named medical UVB (UVBmed).

Irradiance of the lamp was measured repeatedly for durations of 10 minutes over a period of about half a year. The measure-
ments resulted in an averaged irradiance of 18 mW/cm² in the UVBmed spectral range with a standard deviation of 4 %. In the UVBmed range the maximum irradiance was 23 mW/cm². Figure 6 shows consecutive measurements of irradiance and dose at the exit plane of the quartz rod over a period of 60 s after ignition of the lamp. The source reaches its maximum irradiance less than 5 s after ignition. Subsequently the irradiance slightly decreases and the dose increases linearly with time.

Spatial homogeneity of the irradiance was estimated by actinometric methods and pointwise, two-dimensional spectral radiometric measurements. These assessments showed that the deviation of the irradiance from the average value on the radiating surface is less than 15 %.

Applications
The demonstration device described here was specially designed for UVB psoriasis phototherapy. Its radiating area is similar to the laser spot sizes that are typically applied in dermatological phototherapies. Thus it is ideally suited to simultaneously irradiate small skin lesions (see Figure 4).

The irradiance obtained with the electrodeless exciplex lamp demonstration device is much lower than that of most excimer lasers. However, a 10 s irradiation with the device already equals a dose of 6 MED (minimal erythema dose) for the skin type II. This fact was established by analysis of the device’s emission spectrum with the help of the CIE standard erythemal action spectrum (wavelength dependent impact of UV radiation on human skin). Maximum irradiation doses applied in localized narrowband UVB psoriasis phototherapy typically are in the range of 10 to 15 MED per treatment session. Because the dose increases proportionally with the exposure time, the electrodeless exciplex lamp enables short treatment durations of less than 30 s per lesion. This is acceptable for the treatment of small lesions in the range of some cm².

Furthermore a one year clinical test of the electrodeless exciplex lamp demonstration device clarified that the lamp is suitable for hospital use. This clinical study has been carried out at a German hospital with 20 patients suffering from psoriasis vulgaris and plaque psoriasis. For more than 80 % of the patients an improvement of their disease could be obtained by narrowband UVB irradiation with the demonstration device.

Conclusion
Electrodeless exciplex lamps show special features such as high flexibility concerning wavelength and geometry, narrowband emission, and long lifetime. Therefore, they can offer an enormous application potential in photomedical processes. These lamps are particularly well suited for psoriasis phototherapy and represent an economical alternative to dermatologic excimer lasers and DBD lamps. A clinical test of the device has been carried out successfully. For the realization of a commercial RF excited exciplex lamp a further increase of the irradiance and a decrease in equipment size is desirable. This is feasible by optimizing the RF coupling circuits, by applying higher RF powers and by using specially designed well adapted electronics.

References