In Vitro Field Exposition of Skin Cells between 100 GHz and 2.52 THz

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Abstract — Initiated by the German Federal Office for Radiation Protection (BfS) field exposition experiments have been designed to examine genotoxic effects of THz radiation in vitro. Under defined environmental conditions, two different human skin cell types are exposed to continuous-wave radiation at six distinct frequencies between 100 GHz and 2.52 THz originating from different sources of THz radiation. The cell containers are irradiated with free space power densities between 0.1 mW/cm^2 and 10 mW/cm^2 measured traceable to the SI units.

I. Introduction and Background

With the increasing amount of applications utilizing THz radiation appearing on the market (e.g. spectroscopy and quality control inspection systems, communication links and security screening systems) not only ethical questions of technology acceptance arise (e.g. in the case of passenger screening revealing personal details) but also questions of health protection in non-ionizing electromagnetic fields. The International Commission for Non-Ionizing Radiation Protection (ICNIRP) limits the power flux density for general public exposure for the frequency range between 2 GHz and 300 GHz to 1 mW/cm^2 [1]. The limit is based on the thermal damage threshold which has been examined extensively in the microwave frequency range, only. Above 300 GHz no such limits for public exposure exist and safety limits concern laser radiation, only. Depending on the specific laser source, the safety limits are in the range between 1 mW/cm^2 and 100 mW/cm^2 [2]. An early study by Berry et al. [3] shows that human exposure due to terahertz imaging systems is usually well below 1 mW/cm^2. However, the non-thermal effects of non-ionizing radiation is still discussed controversially. In the THz frequency range, only one comprehensive study exists so far [4]. Korenstein-Ilan et al. found increased genomic instability in human lymphocytes for exposure to 100 GHz radiation well below the safety limit (0.031 mW/cm^2 in culture medium) [5]. Accordingly, the German BfS aims to further examine possible non-thermal effects and verify their existence. This includes not only the search for aneugenic effects but also the search for possible genotoxic effects which are assumed that they cannot be caused by non-ionizing radiation.

II. Project Description

In this project, two different human cell types, i.e. the HaCaT keratinocyte cell line and primary dermal fibroblasts, are exposed to THz radiation, since the penetration depth into the human body above 100 GHz is well below 1 mm [4]. The cells are cultivated in DMEM medium in a custom built sample container as shown in Fig. 1. The bottom of this container consists of a 200 µm thick foil transparent in the THz frequency range on which the cells are fixed in a spot of 12 mm diameter in the center. The cells are irradiated in a modified incubator at six distinct frequencies of 100 GHz, 130 GHz, 385 GHz, 604 GHz, 1.63 THz and 2.52 THz to verify the results from previous studies and to cover a larger part of the THz frequency range. Four different sources of THz radiation are used to irradiate the exposition zone with a 2 cm diameter Gaussian beam from below, respectively: a frequency multiplier cascade at 100 GHz, a Gunn oscillator at 130 GHz, a backward-wave oscillator at 385 GHz and a far-infrared gas laser at 604 GHz, 1.63 THz and 2.52 THz. For each source, three power flux densities below, at and above the limit (0.1 – 10 mW/cm^2) are chosen for the exposure. All power densities will be measured traceable to the SI units [6] in order to allow for a precise and reliable assessment of the exposure dosis.

During exposition, the sample containers are kept at defined environmental conditions of 37 °C and 5 % CO_2 content of the atmosphere in a modified incubator as required by the cells. The exposition geometry is shown in Fig. 2. All experimental parameters are permanently monitored during the exposition experiments. Two different exposure times of 2 h and 8 h are chosen. The comet assay is used as biological end point for strand breaks [7], whereas the micronucleus test is chosen to search for possible aneugenic and clastogenic effects [8]. Fig. 3 shows typical outcomes of the two end points. The validity of the results is guaranteed by positive controls, sham exposition experiments and a blinded experimental procedure. In order to obtain statistically significant results, four independent experimental series are conducted.

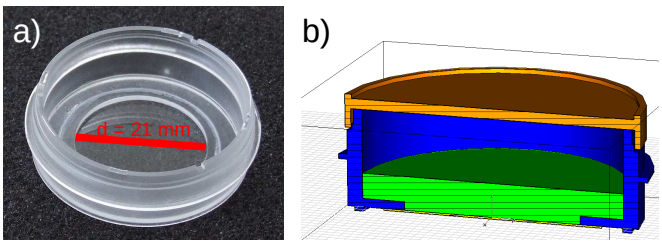

Fig. 1: a) Custom-built sample container for the field exposition experiments with the lid removed. b) Computer model in CST Microwave Studio used for the calculation of the specific absorption rate (SAR) in the cell container filled with culture medium.

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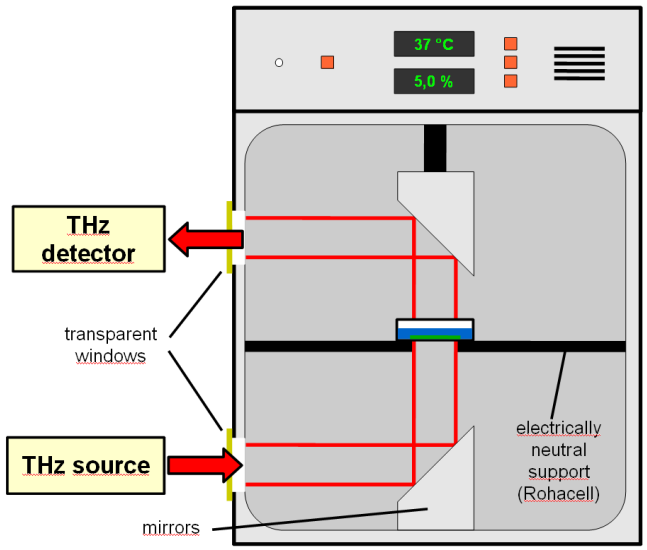

Fig. 2: Modified incubator with sample container fixed in the center of the Gaussian beam. The source is coupled through a transparent window. A second window allows for the monitoring of the THz beam if no sample container is present. The inner walls of the incubator are covered with absorber foil to prevent standing waves.

III. Dosimetric Calculations

First dosimetric calculations to quantify the power introduction into the cell layer have been performed using the finite differences time-domain method as implemented in the program CST Microwave Studio. Fig. 4 shows the calculated SAR distribution at 100 GHz after irradiation of the sample container with a homogeneous wave having a field strength of 100 V/m. The results indicate, that heating effects probably cannot be neglected at higher exposure levels when evaluating the outcome of the experiments.

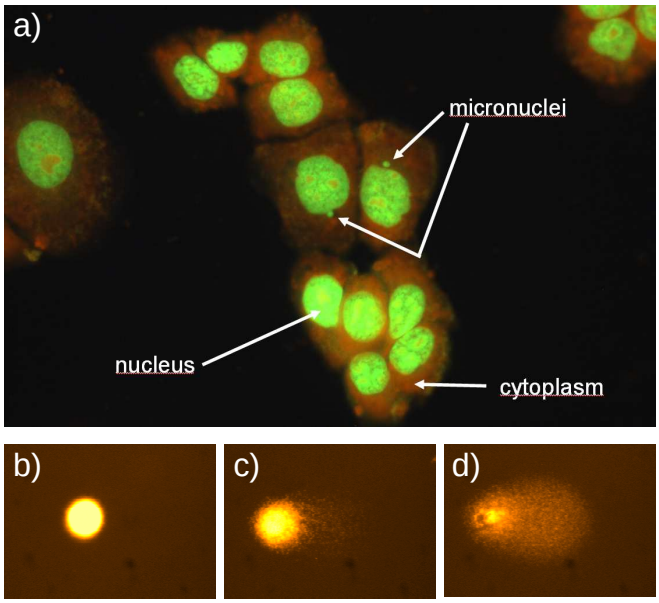

Fig. 3: a) Micronuclei in the HaCaT keratinocyte cell line. b) Undamaged, c) slightly damaged and d) strongly damaged DNA of HaCaT keratinocyte cell as seen in the comet assay.

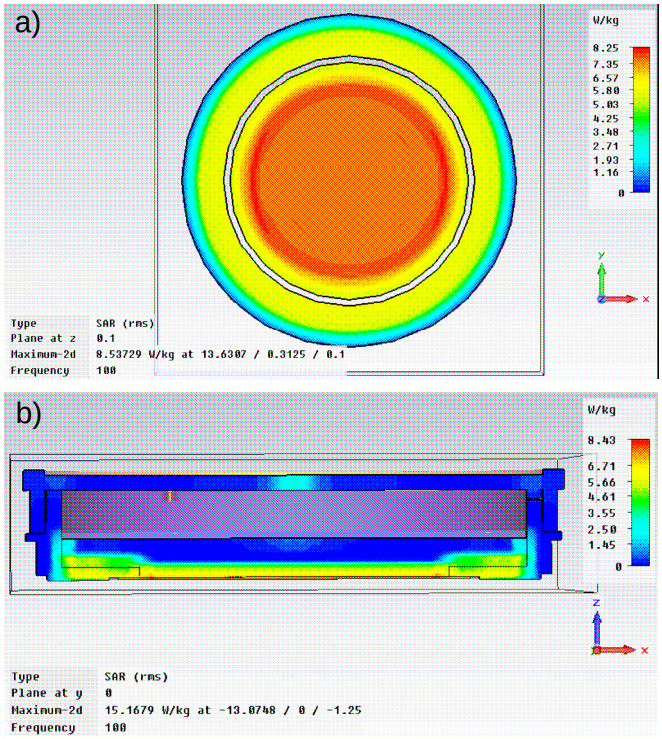

Fig. 4: Distribution of the specific absorption rate (SAR) averaged over 0.01 g in a cell container filled with culture medium. The container is irradiated with a homogeneous wave at 100 GHz traveling in positive z-direction having a field strength of 100 V/m (power flux density of 2.65 mW/cm^2). a) cut plane 100 µm above the bottom, b) cross-section.

IV. Conclusion

In this contribution we have shown the design and parts of the characterization of the experimental setups and first dosimetric calculations for a comprehensive study on possible genotoxic effects of THz radiation as initiated by the German Federal Office for Radiation Protection. Field expositions are currently underway. Results of the experiments are expected in 2010.

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