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Laser wakefield accelerator for very high energy electron beam therapy

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The development of laser wakefield accelerators[1] has made it possible to develop compact, high-energy electron beam accelerators. By using this compact accelerator, it is possible to develop cancer treatment technology using high-energy electrons that are different from existing treatments. As an alternative to cancer therapy using conventional RF based linear accelerators, a very high energy electron (VHEE) beam from laser wakefield accelerator has been studied because of its clinical advantages compare to existing x-ray method[2]. Among these advantages, important effects are the deep internal organ treatment because of deep penetration of the VHEE beam, unlimited irradiation direction due to the low effect of dose profile of VHEE beam by the human body's internal interface, and the easy irradiation direction adjustment by electromagnetic field. The laser wakefield accelerator uses a strong acceleration field to obtain high energy at a short acceleration distance, making it easy to develop compact treatment equipment.

For the development of such application, an electron beam was accelerated using a laser wakefield accelerator and the medical properties of the accelerated electron beam were measured. A 33 fs, 16 TW laser was used to accelerate electron up to 170 MeV. Experimental setup and the accelerated electron beams are shown in Fig. 1. a) and b). For each shot, the plasma properties such as density profile and shape of the plasma are measured simultaneously to optimize the accelerator. After the accelerator, integrated current transformer and bending magnet was used to measure the bench charge and the energy of the beam.

Medical properties such as percent depth dose and radio biological effect (RBE) were measured with a solid phantom, EBT3 film, and cancer cell. Due to the high energy, the dose distribution in the form of a pencil beam with small dispersion was observed, and the dose was delivered to a deep place. The maximum dose was almost linear with the total charge so the total dose was controlled by the total charge deposited to the cell for the RBE measurement. The survival fraction was measured by counting the living cell after the exposure. By this method, the measured RBE was 1.2 ~ 1.3. From the measured medical properties of the VHEE beam, a laser wakefield accelerator could be used for therapy system. This work was supported by the Korea Medical Device Development Fund grant funded by the Korea government(Project No: KMDF_PR_20200901_0085, 9991006758).

References

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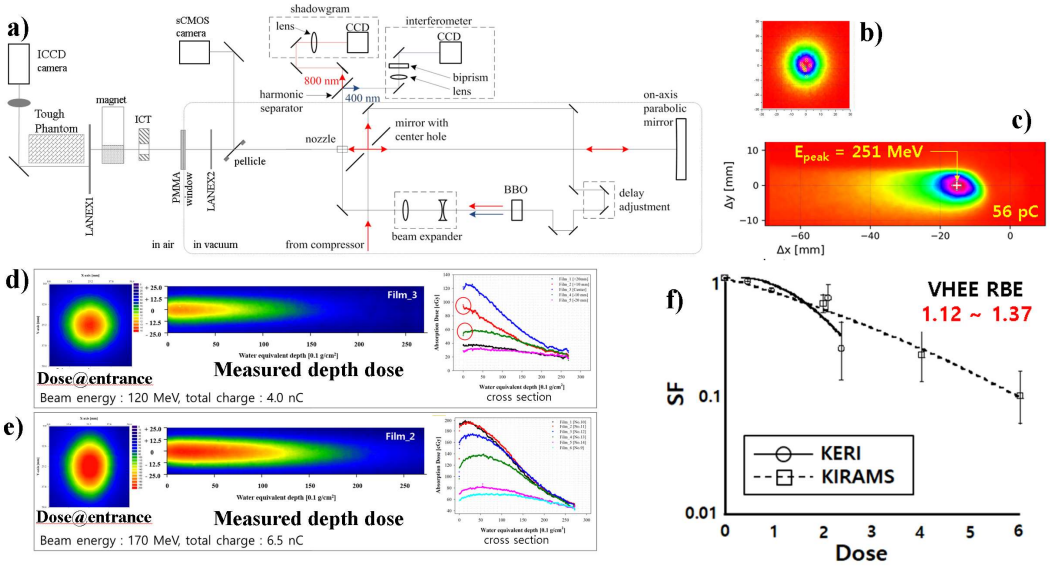

Figure 1. Generation of VHEE beam and the measured physical properties for cancer therapy. a) shows the experimental setup. b) and c) are the electron beam shape and energy profile. At b), yellow dots show the position of the beam center for each shot. d) and c) show the measured depth dose profile with different electron energy. f) shows the measured RBE.