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Medical application of high energy electron beams by laser wakefield accelerator

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A laser wakefield accelerator (LWFA) has the advantage to design a compact accelerator system because it can generate a high accelerating field in a small area compared to conventional systems [1]. The LWFA has attracted much interest because of its potential applications such as ultra-short X-ray source, particle beam irradiation and medical applications. In particular, the very high energy electron (VHEE) beam therapy, in the energy range of 50 MeV to 250 MeV, has been studied because it has clinical advantages over conventional X-ray methods, such as deep site treatment due to the deep penetration depth and easy adjustment of the irradiation direction with electromagnetic field [2~4]. These properties mean that laser wakefield accelerators are good candidates for compact high-energy electron accelerators.

In this study, electrons were accelerated by a 20TW Ti:sapphire laser-based LWFA system to measure the medical properties of the VHEE beam as a radiotherapy system. The laser intensity was 6.3×10^{18} W/cm^2 and normailzed vector potentail, a0, was 1.75. A gas target was used mixture 90% helium and 10% nitrogen. The plasma density and profile were measured with an interferogram and a shadowgram, respectively. The beam diagnostic of VHEE beam was measured by intergrated current transformer (ICT), Scintillator screens (LANEX). The electron beam diameter measured 100 irradiation was 8.7±0.4 mm, and the beam divergence were 1.4 mrad in the horizontal and 6.3 mrad in the vertical direction, respectively. The averatged chrage was 65±16 pC and, the total charge of VHEE beam for percentage depth dose curve (PDD) was 6.5 nC. The peak energy of each individual electron beam energy measured is 170 MeV with a standard deviation of 18 MeV. The three-dimensional PDD of the electron beam was measured using a tough phantom composed of Gafchromic films, and the relative biological effectiveness (RBE) was measured from the cell survival ratio. In addition, the irradiation direction of the electron beam was measured as a function of the electromagnetic field strength after LWFA. The PDD of the electron beam has a low divergence characteristic of the high energy electron beam and the size-preserving shape of the electron beam, known as the pencil beam, was measured. The PDD results aere compared with the Monte Carlo calculation for mono-energetic electron beam. The RBE was measured to be 1.2~1.3.

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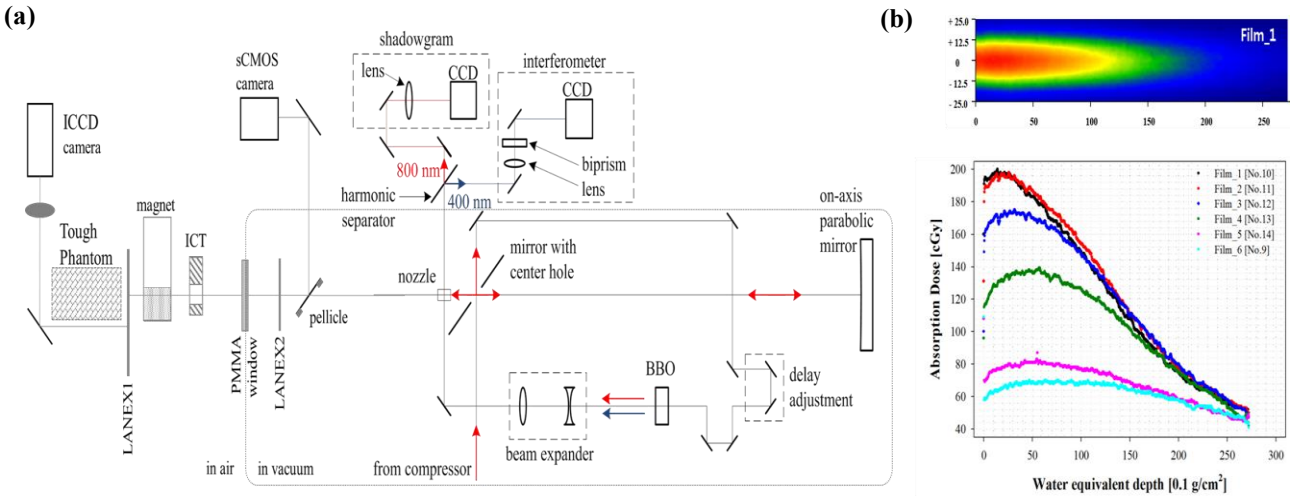

Figure 1. Experimental setup and results (a) Schematic of the target chamber of laser wakefield accelerator at the KERI. (b) Dose profile of VHEE beam at the penentrated depth