Terawatt Ultrafast High Field Facility

Radiation chemistry studies reactions occurring after the interaction of ionizing radiation in the form of highly energetic particles with matter. Radiolytic techniques make it possible to generate species that cannot be produced easily in other ways. Our research is directed towards the development of a better understanding of the fundamental interactions that exist between ionizing radiation and matter. Important questions surrounding the primary events in radiation chemistry include: What is the role of excess energy in chemical reactions of neutrals, ions and radicals or in ion solvation? What is the mechanism of charge transfer in the condensed phase? What are the mechanisms of the ultrafast chemical reactions that occur between pre-thermalized species? Fundamental studies of these chemical processes provide a basis for the use of radiation in diverse technologies, including nuclear energy production and waste storage, environmental remediation, catalysis, and biological agent destruction.

Some insight into these very important phenomena has been gained from ultrafast laser experiments and theoretical simulations. To truly understand how the primary processes determine the secondary effects (yields, defect identification, etc.) it becomes necessary to develop subpicosecond pulse radiolysis tools. Table-top terawatt laser (T^3) based particle accelerators offer the possibility to push the time resolution to the subpicosecond regime. Development of ultrafast methods of radiation chemistry, such as those being worked on at Argonne, promise to open up entirely new windows for observing these important processes.

Recent advances in table-top laser technology have made it possible to generate peak powers in the multi-terawatt regime. These ultra-intense light sources have provided impetus for renewed interest in high field sciences and the pursuit of subpicosecond radiation sources. For example, these relatively compact laser systems have been used to generate intense femtosecond x-ray pulses (out to ~10-20keV). Of interest to the field of radiation chemistry is the ability to achieve focal intensities well in excess of 10^{18}W/cm^2, the threshold for the onset of nonlinear relativistic optical effects. At intensities above 10^{18}W/cm^2 it becomes possible to accelerate charged particles such as electrons and protons to relativistic velocities.

Through a collaboration with the Center for Ultrafast Optical Studies (CUOS) at the University of Michigan we have demonstrated that the charge produced by a laser based accelerator is adequate for use in chemical studies. In our initial experiment we ionized liquid water with the electron pulses generated by the CUOS T^3 and subsequently monitored the quantity of the hydrated electron that is produced on the microsecond time-scale. The experiment shows, for the first time, that a laser based electron accelerator can produce sufficient charge to conduct time resolved investigations of radiation induced chemical events and that terawatt lasers offer a means to achieve subpicosecond time resolution for pulse radiolysis studies.

In the Chemistry Division we have constructed the Terawatt Ultrafast High Field Facility that will provide a source of tunable femtosecond x-rays and electron pulses for chemical studies. TUHFF houses a T^3 system that generates .6J 30fs (20TW) laser pulses at 10Hz. We have recently succeeded in using the T^3 to accelerate electrons to energies ~5MeV. Electron acceleration was achieved by tightly focusing the terawatt laser pulses into a supersonic helium gas jet. Figure 1 shows a picture of the target chamber used to accelerate the electrons. Currently, we are working on optimization of the electron beam for use in pump-probe experiments.

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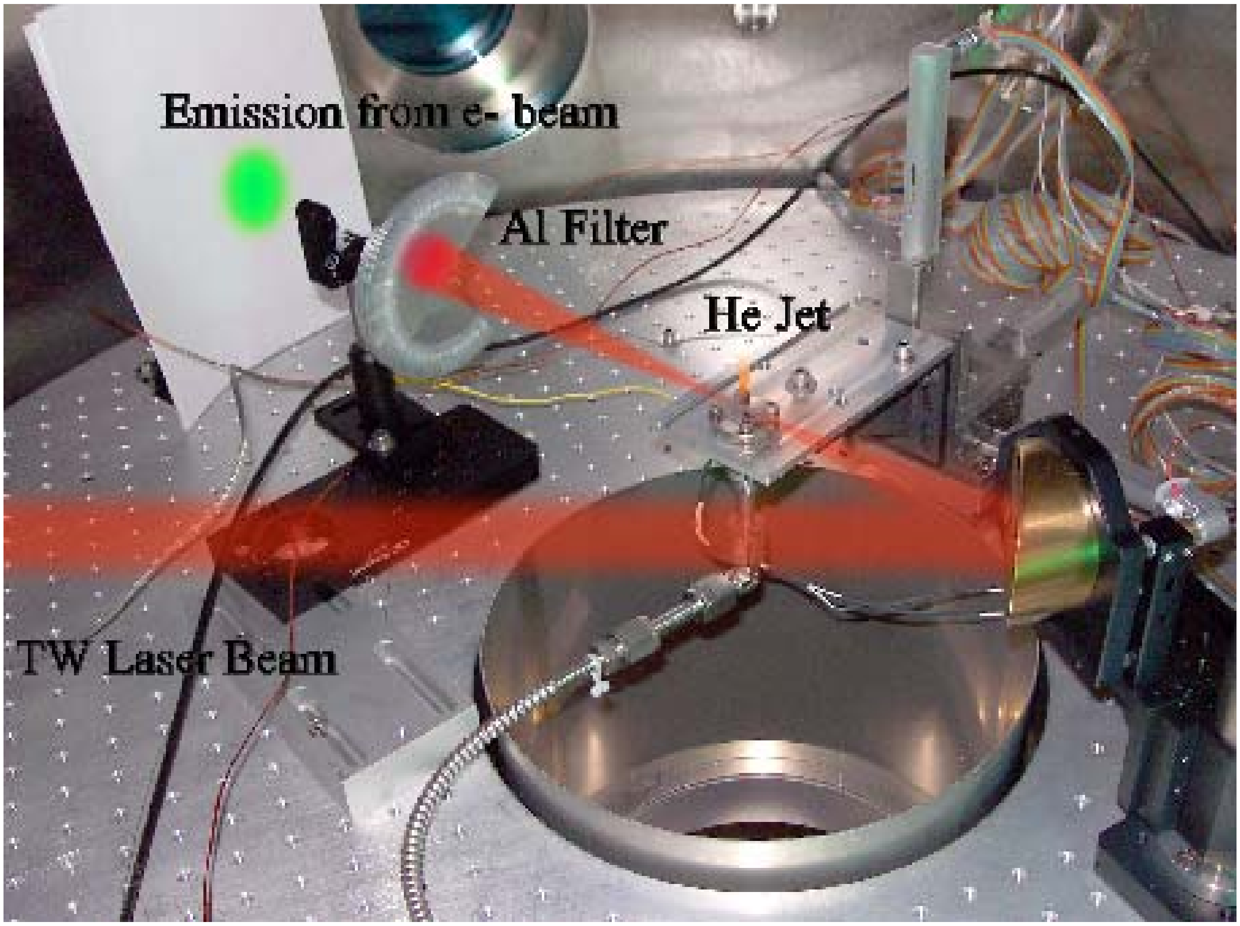

Figure 1. Generation of relativistic electrons at TUHFF. A terawatt laser beam enters from the left and is focused into a supersonic helium gas jet by an off axis parabolic mirror. A aluminum filter after the gas jet transmits electrons with energy >~4MeV which then produce a green emission on a phosphor screen.