# VIII-C Developments and Researches of New Laser Materials

Although development of lasers is remarkable, there are no lasers which lase in ultraviolet and far infrared regions. However, it is expected that these kinds of lasers break out a great revolution in not only the molecular science but also in the industrial world.

In this project we research characters of new materials for ultraviolet and far infrared lasers, and develop new lasers by using these laser materials.

## VIII-C-1 Intense THz Radiation from Femtosecond Laser Pulses Irradiated InAs in a Strong Magnetic Field

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Since the first observation of THz radiation from InAs surface irradiated with femtosecond laser pulses, considerable effort have been made to design an intense THz-radiation source and to understand the mechanism for generating THz radiation. However, the problem has not been solved. In this paper, we have investigated the intense THz radiation from InAs by applying a strong magnetic field up to 5 T. We compared several different geometries. Besides quadratic magnetic field dependence, we found saturation of the THz-radiation intensity around 3 T. Furthermore, the intensity decreased dramatically above 3 T. It represented that the most suitable magnetic field was 3 T to design an intense THz-radiation source. We also took spectra by a Polarizing Michelson interferometer. The spectral shapes for the different magnetic field directions were significantly different. The center frequency of these spectra shifted to lower frequency with increasing magnetic field. Through these experiments, we found the best configuration and the most suitable magnetic field to obtain an intense THz radiation for various applications such as imaging, sensing, and spectroscopy. This configuration dependence of the spectral shape and the center frequency is attributed to be the initial carrier acceleration processes modulated by a strong magnetic field.

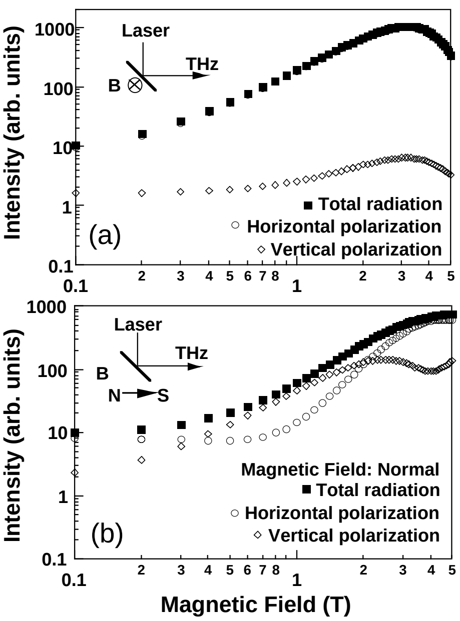


**Figure 1.** Magnetic field dependence of THz-radiation intensity. Inset indicates the experimental geometry. Closed squares, open circle and diamonds show total radiation, horizontal and vertical polarization, respectively. (a) The saturation of THz radiation intensity is clearly observed. (b) The saturation is not observed.

## VIII-C-2 High-Repetition-Rate, High-Average-Power Mode-Locked Ti:sapphire Laser with an Intracavity cw-Amplification Scheme

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We have demonstrated a high-average-power, mode-locked Ti:sapphire laser with an intracavity cw-amplification scheme. The laser generated 150-fs pulses with 3.4-W average power at a repetition rate of 79 MHz. This simple amplification scheme can be applied for the power scaling of other lasers.

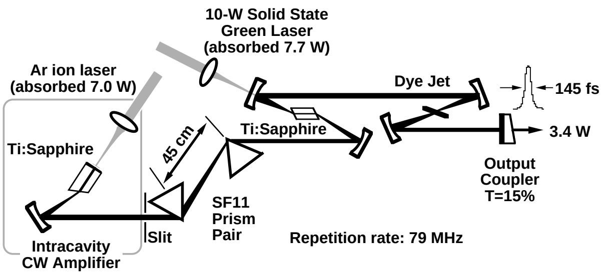


**Figure 1.** Configuration of high-repetition-rate high-average-power (3.4 W) femtosecond Ti:sapphire laser with an intracavity cw amplifier. The half-cut Brewster Ti:sapphire crystal composed the intracavity cw amplifier.

## VIII-C-3 Compact THz-radiation Source Consisting of a Bulk Semiconductor, a Mode-Locked Fiber Laser, and a 2-T Permanent Magnet

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Various THz-radiation sources have been intensively studied including photo conductive switches irradiated with ultrashort optical pulses. An intense, compact, and simple light source is required for applications in sensing or imaging. We have demonstrated the strong enhancement of THz-radiation power with a magnetic field by using an InAs semiconductor. In this paper, we report on a compact THz-radiation source consisting of a fiber femtosecond laser and a newly designed 2-T permanent magnet shown in Figure 1. A mode-locked frequency doubled Er-doped fiber laser delivered 170-fsec pulses at 780 nm with a 48.5-MHz repetition rate (IMRA model FA7850/10SA) with 30-mW average power and 4.1-kW peak power. The mode-locked fiber laser is a completely turn-key system. It is much smaller than a mode-locked Ti:sapphire laser that requires daily alignment. The used semiconductor sample was undoped bulk InAs with a (100) surface. The 2-T permanent magnet unit consisted of 8 Nd-Fe-B magnet pieces. The remanence magnetic field of the Nd-Fe-B material itself was 1.3 T (NEOMAX-44H). Owing to the new magnetic circuit design, the magnetic field in the center exceeded the remanence magnetic field of the material. The permanent magnet only weighs about 5 kg. The 2-T permanent magnet unit is smaller and much lighter than an electromagnet. At present the average power is estimated to sub-micro watt level. The spectra of the THz radiation were obtained by a Polarizing Michelson interferometer. Many water vapor absorption lines were clearly observed. Therefore, the THz-radiation source is already usable for spectroscopy. Such a simple and compact source will open up new application for THz-radiation.

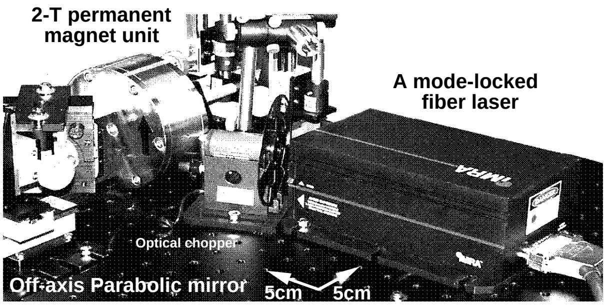


**Figure 1.** Photograph of a compact THz-radiation source with a bulk semiconductor, a fiber femtosecond laser, and a 2-T permanent magnet. Including the laser, the size is less than 40 × 30 × 15 cm.

## VIII-C-4 Spectrum Control of THz Radiation from InAs in a Magnetic Field by Duration and Frequency Chirp of the Excitation Pulses

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The THz-radiation spectrum from InAs in a magnetic field irradiated with femtosecond pulses can be controlled by varying the excitation pulse width and chirp direction of the excitation pulse. A longer excitation pulse width produces lower frequency THz radiation. Also, positively chirped pulse excitation will generate higher power and higher frequency THz radiation, due to the corruption of the impulse response of the semiconductor in the longer pulse width region. The spectral shape of the radiation strongly depends on the chirp direction. This unexpected difference with the same excitation peak power and the same pulse duration with different chirp direction is rather surprising. This difference of THz-radiation for the chirping of the excitation pulses might be attributed to the difference of the photo-carrier relaxation process in the conduction band with oppositely chirped-pulse excitation.

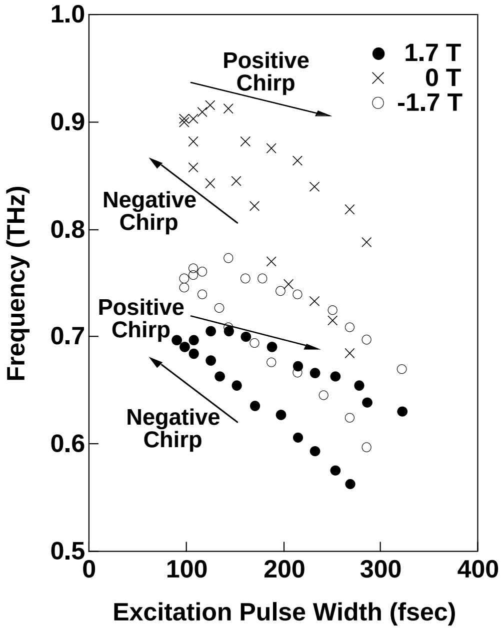


**Figure 1.** Center frequency spectrum dependence of THz radiation with different excitation chirp, pulse duration and magnetic field. Close circle, open circle and cross show 1.7 T, –1.7 T and 0 T, respectively.

## VIII-C-5 LiCAF Crystal as a New Vacuum Ultraviolet Optical Material with Transmission down to 112 nm

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$LiCaAlF_6$ (LiCAF) was found to be an ideal optical material for the vacuum ultraviolet region due to its superior transmission characteristic of down to 112 nm, its non hydroscopic nature, and its better mechanical properties compared with LiF.

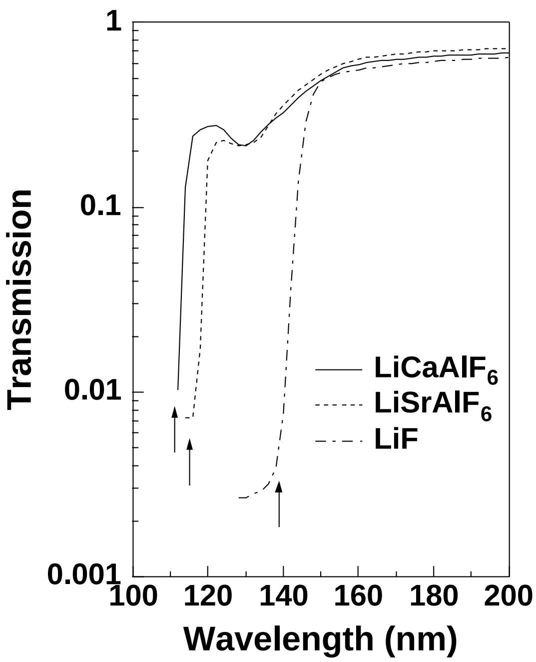


**Figure 1**. Transmission characteristics of LiCAF, LiSAF, LiF.