Present Status of the Electron Accelerator Facility at the ETL

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Abstract

An electron linac TELL and three storage rings, i.e. TERAS, NIJI-II, and NIJI-IV, form the "electron accelerator facility" of the Electrotechnical Laboratory. TELL is mainly used to produce high-intensity slow-positron beam and to fill storage rings. The research in solid-state physics by means of slow-positrons is performed in the low-energy experimental room and the adjoining room. A compact storage ring NIJI-II equipped with the Onuki-type polarizing undulator is located in the medium-energy experimental room. The free-electron laser (FEL) research is under way with NIJI-IV located in the pion room; this ring often attains the world shortest record in FEL wavelength. TERAS is a multi purpose storage ring. Among a variety of experimental research programs made at TERAS, one for generation and utilization of monochromatic polarized photon beam is mentioned.

1 Introduction

The electron accelerator facility of the Electrotechnical Laboratory (ETL) consists of an electron linac, TELL, and three storage rings, TERAS, NIJI-II, and NIJI-IV. TELL is surrounded by five experimental rooms: low-energy experimental room (L-En Rm), medium-energy experimental room (M-En Rm), high-energy experimental room (H-En Rm), pion room (P Rm), and ring room (Ring Rm). TELL was constructed in 1980 [1] and was originally intended to share electron beams with two or three experimental rooms simultaneously. However, for a variety of reasons, we decided to transport electron beams into one experimental room at one time.

Figure 1 shows the operation statistics of TELL for the latest five fiscal years. In this figure, "Acc Rm" means the total hours when some experiments or maintenance works were made inside the linac room, whereas other symbols mean the total hours when all the accelerated electrons were ready to transport into the corresponding experimental room.

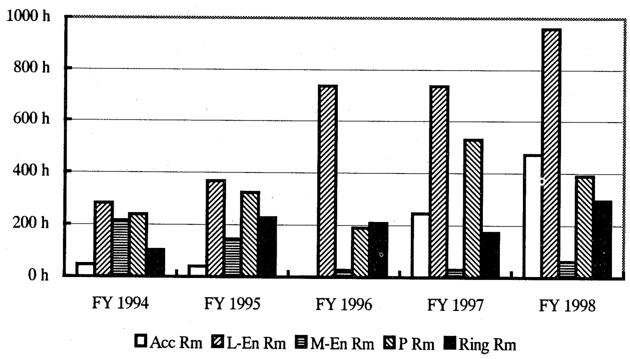

Fig. 1 Total hours dedicated to individual experimental rooms in the period of Apr. 1994 – Mar. 1999.

In the following sections, we describe several research programs made at the electron accelerator facility. Research projects related with the Onuki-type polarizing undulator are presented in a little detail.

2 Slow-Positron Production

In the L-En Rm, ~70-MeV electrons hit a Ta target (an electron-to-positron converter) and generate a large amount of positrons. The positrons enter a stack of very thin W foils (a positron moderator) and $\sim 10^8$/s of slow positrons emerge from the moderator. The slow-positron pulses, whose duration is ~1 μs and repetition rate is usually 100 pulses/s, are converted into a quasi-continuous beam by a linear storage section. The quasi-continuous beam is converted to a pulse train of more than 10^5 pulses/s of slow positrons having ~100-ps width by a novel time-bunching system. We use the high-intensity and very short pulses of slow positrons to study structures of various solid materials or thin films at surfaces, near surfaces, or interfaces by measuring positron lifetime spectra [2]. We also constructed a neat apparatus for positron-annihilation induced Auger-electron spectroscopy to characterize topmost states of solids with high-resolution and high-count rate [3]. For the purpose of increasing the intensity of slow positrons much higher, we have investigated the moderation efficiency of various materials. We found that a 6H-SiC(n) crystal is suitable as a re-moderator for a multi stage brightness enhancement system [4]

3 Monochromatic Polarized Photon Generation

By the use of TERAS, which is installed in the Ring Rm, we generate monochromatic polarized photon beam through the laser Compton scattering processes. The photon beam is used for various experimental studies, *e.g.*, nuclear physics, measurement of cross sections of photo-induced reactions, construction of a novel neutron source, and so on [5].

The construction of a pilot system to generate ~10-nm photons was started in Apr. 1998 in the Acc Rm [6]. The final target of the new project is to realize a light source for the future x-ray lithography.

4 Free-Electron Laser

We have conducted the free-electron laser (FEL) project with NIJI-IV in the P Rm. One of the recent

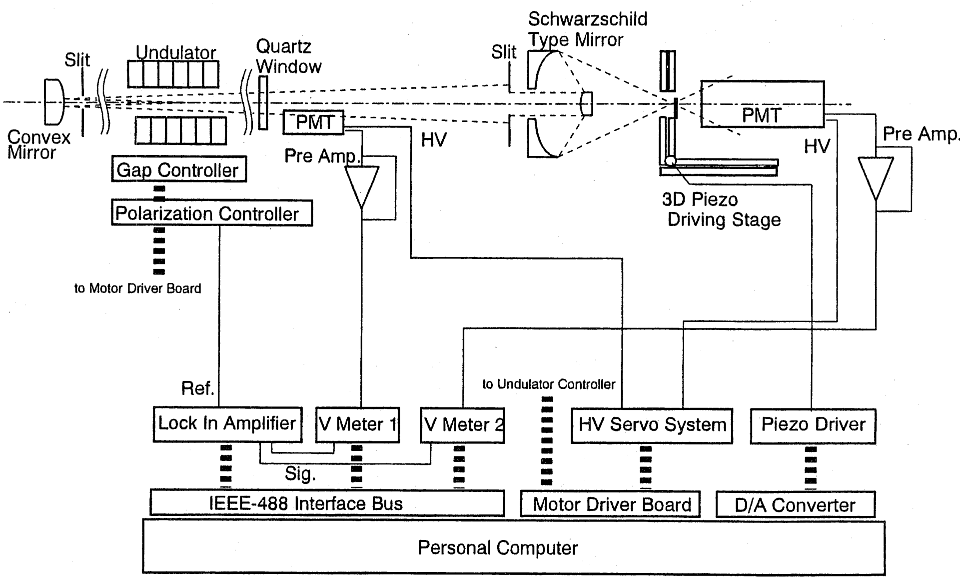

Fig. 2 Schematic diagram of the system for microscopic imaging of CD. Circularly polarized radiation from the undulator is reflected by a convex mirror and is focused at the sample in 3D Piezo-driving stage by a Schwartzschild-type mirror.

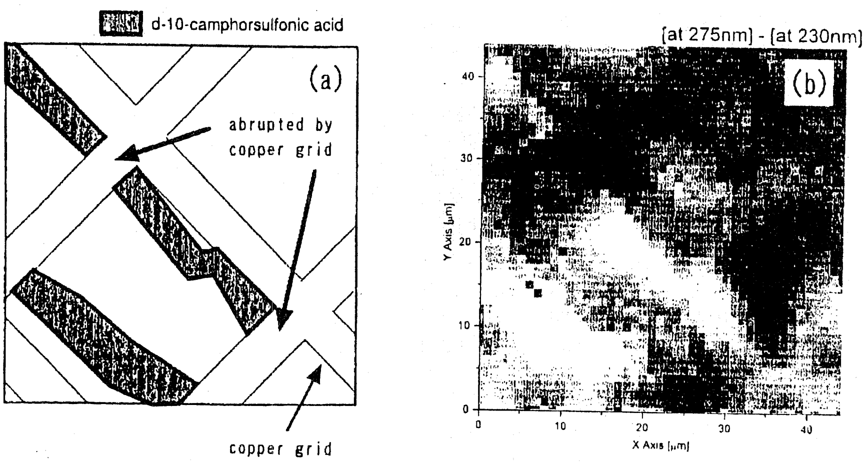

Fig. 3 (a) Schematic view of sample arrangement on a copper grid (black areas indicate the sample). (b) CD image of dried d-10-camphorsulfonic acid films on a copper grid by subtracting the image at 230 nm from that at 275 nm (white areas indicate strong CD signals of the sample on the contrary to (a)).

prominent topics of the program is that we succeeded in lasing at 212 nm in Oct. 1998, which has been the world shortest record until very recently. The important factors contributing to the lasing in the UV region such as improvement of the RF system and others made in NIJI-IV are reported in this symposium [7].

5 Polarizing Undulator

The Onuki-type polarizing undulator (PU) [8] proposed and developed in the ETL which produces high brilliant, quasi-monochromatic, wavelength-variable, and polarized synchrotron radiation (SR) of any ellipticity is installed at NIJI-II in the M-En Rm. The SR emitted from the PU is used for various research fields; we describe three major research subjects in this section.

5.1 Microscopic Imaging of Circular Dichroism

We developed a new type of scanning microscope to observe circular dichroism (CD) images of samples [9]. The PU, which generates right- and left-handed circularly polarized SR alternately, was used as an illuminating light source. The SR from the PU was focused to form a microbeam with the spot size of less than 1 μm by axially symmetric mirrors. The sense of the rotation of the circular polarization of the undulator radiation (UR) was modulated with a frequency of ~2 Hz. Figure 2 shows schematic diagram of the CD microscope. Two-dimensional CD image of thin film of d-10-camphorsulfonic acid, which is one of standard samples for the measurement of CD spectrum, was obtained by this microscope. Figure 3 is the final CD image, which was derived by subtracting the image signal obtained at 230 nm from that at 275 nm.

5.2 Optically Controlled Alignment of Liquid Crystal

Liquid crystal (LC) alignment properties on photo-exposed polyimide films were studied in the UV and VUV

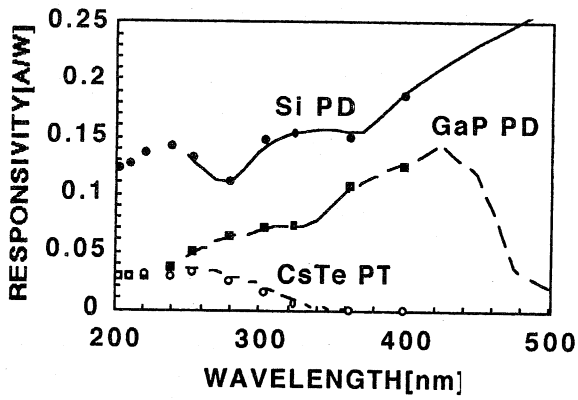

Fig. 4 Calibration results for Si, GaP photodiode, and CsTe phototube using monochromatized UR based on ESR. Also shown by lines are calibration results based on present ETL responsivity scale.

regions using linearly polarized SR from the PU [10]. We found that the LC alignment uniformity depends on the UV and VUV exposure conditions, especially on the SR wavelength. The photoabsorption spectrum of polyimide films was also measured in both UV and VUV regions. We conclude that at least two mechanisms exist in the photo-induced alignment of LC molecules on the polyimide films.

5.3 Calibration of UV Detectors

Thermal detectors are often used to extend available spectral range of established detector standards because their responsivities are constant with wavelength. However, the use of thermal detectors is very limited because of their low responsivity. In order to increase responsivity of thermal detector, its photoreceiver has to be furnished as thin and small as possible; which results in structural fragility and small active area. As long as a conventional light source such as a quartz halogen lamp or a deuterium lamp is used, it is necessarily required that a detector used for calibration is irradiated in a large solid angle. In this case, the calibration result probably differs from that using a parallel beam. It was reported for Si and GaAs photodiodes that this difference becomes large in the UV and VUV regions. In order to overcome the above problems, we decided to use UR as an intense UV radiation source for detector calibration based on Electrical Substitution Radiometer (ESR). We have calibrated a Si photodiode (Hamamatsu S1337), a GaP photodiode (Hamamatsu G1963), and a CsTe phototube against a room-temperature-operated ESR using UR monochromatized by an interference filter.

Figure 4 shows the calibration results using monochromatized UR measured with an ESR. The present results are compared with those based on a current ETL responsivity scale (shown by lines) using traditional light sources (quartz halogen lamp and deuterium lamp) and a monochromator. The ETL responsivity scale was established in the wavelength range longer than 250 nm. It is found that the present calibration results using UR for a Si photodiode, a GaP photodiode, and a CsTe phototube agree with the existent scale within ±4%, ±5%, and ±17%, respectively.

6 Concluding Remarks

Research programs using directly or indirectly electron beam accelerated with TELL are described briefly. We have made serious efforts to maintain and operate all the apparatus. TELL has fortunately worked very well for ~20 years without replacements of key components though a lot of troubles have occurred from time to time. We keep using the present facility to proceed the existing research programs by fixing or repairing various components, on the one hand: We seek appropriate funds for renewing the facility, on the other hand.

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