ELECTRON ACCELERATOR FACILITY AT THE AIST

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Abstract

The electron linac TELL at the National Institute of Advanced Industrial Science and Technology (formerly known as the Electrotechnical Laboratory) was in "ready-to-operate" mode for 2,000 and 1,300 hours in fiscal year 1999 and 2000, respectively. One of the recent topics attained in research programs using slow-positron beam is that we showed the feasibility of controlling the dielectric constant of thin films by adjusting low-frequency power in plasma-enhanced chemical vapor deposition processes. We constructed a radiography system using high-energy x rays produced with laser-Compton scattering processes at TERAS. Various improvements have been made at NIJI-IV to accomplish oscillation of free electron lasers in the vacuum ultraviolet region.

1 INTRODUCTION

Laboratories and institutes attached to the Agency of Industrial Science and Technology, Ministry of International Trade and Industry, were united to one institute on April 1st, 2001. The reorganized institute is named the National Institute of Advanced Industrial Science and Technology (AIST). The electron linac TELL is managed mainly by the Photonics Research Institute with the assistance by the Metrology Institute of Japan, AIST.

TELL is used to produce high-intensity slow-positron beam and to fill three storage rings, viz., TERAS, NIJI-II, and NIJJ-IV. Solid-state physics using slow-positron beam is studied in the low-energy experimental room (L-En. Rm). The storage ring NIJI-II is located in the medium-energy experimental room (M-En. Rm) and is equipped with the Onuki-type polarizing undulator. The storage ring NIJI-IV solely dedicated to the free-electron laser (FEL) experiments is in the pion experimental room (P Rm). One more storage ring TERAS, which has worked since 1981, is in the ring room (Ring Rm).

The operation statistics of TELL for the latest two fiscal years (FY's) is shown in Fig. 1. In this figure, "Acc. Rm" means the total hours when experiments or maintenance works were made inside the linac room, whereas other symbols mean the total hours when all the accelerated electron beams were ready to transport into the corresponding experimental room. Total hours in FY 2000 was about 1,300 hours whereas that in FY 1999 was about 2,000 hours. This decrement in FY 2000 was mainly caused by a series of engineering works to renew cooling-water system of TELL.

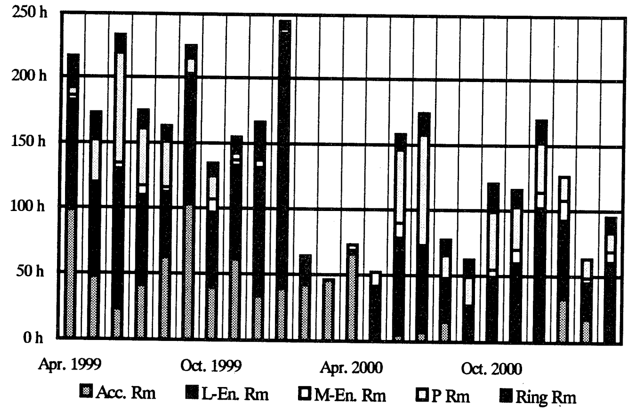

Figure 1: Total hours dedicated to each experimental room from April 1999 to March 2001.

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2 RESEARCH PROGRAMS USING TELL

In this section, we describe several research programs made with the electron accelerator facility at the AIST.

2.1 Positron Lifetime Spectroscopy

In the L-En. Rm, we generate ~10^8 slow positrons/s by using ~70-MeV electrons bombarding a Ta target and a W-foil moderator. We constructed a facility for the positron annihilation lifetime spectroscopy (PALS). The PALS technique is suitable to detect nondestructively open volume type defects in a solid material. By the use of the PALS system, we measured lifetime distribution of positrons and ortho-positronium (o-Ps) in low-dielectric-constant films. The samples were hexamethyldisiloxane-based thin films formed by plasma-enhanced chemical vapor deposition (PECVD) with dual-frequency power sources [1]. Figure 2 shows the lifetime distributions of positrons in the films at an incident energy of 3 keV. As clearly shown in Fig. 2, all the lifetime distributions have long-lived components being caused by o-Ps pick-off annihilation.

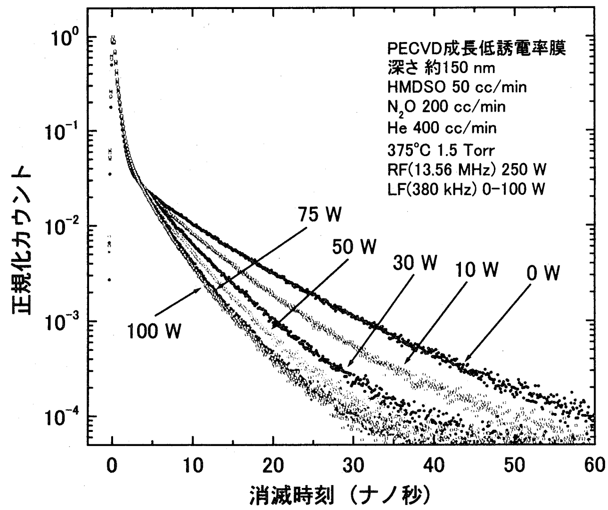

Figure 2: Positron lifetime distributions for the hexamethyldisiloxane-based thin films formed by dual-frequency PECVD.

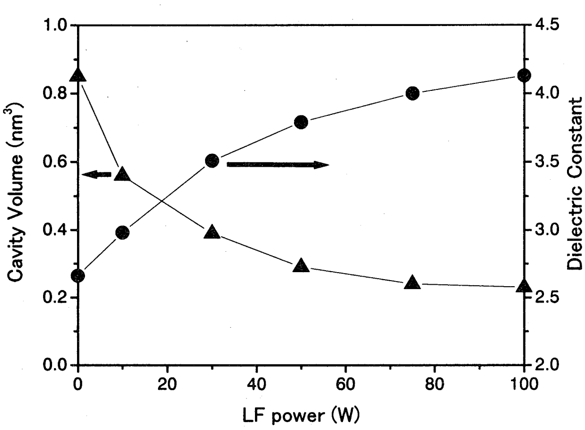

Figure 3: Cavity volume (triangles) and dielectric constant (circles) vs. LF power of the PECVD process.

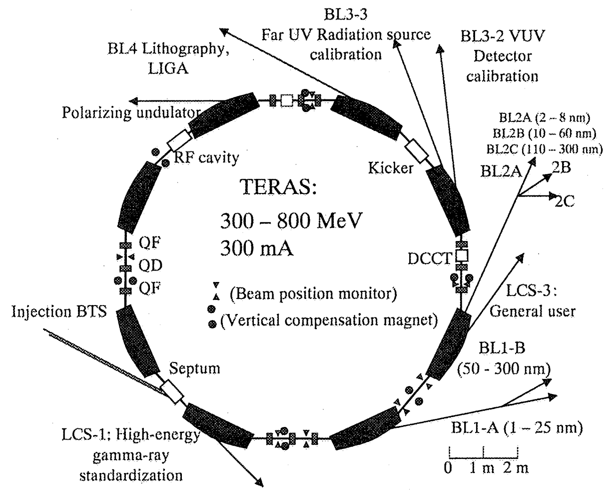

Figure 4: Plan view of storage ring TERAS.

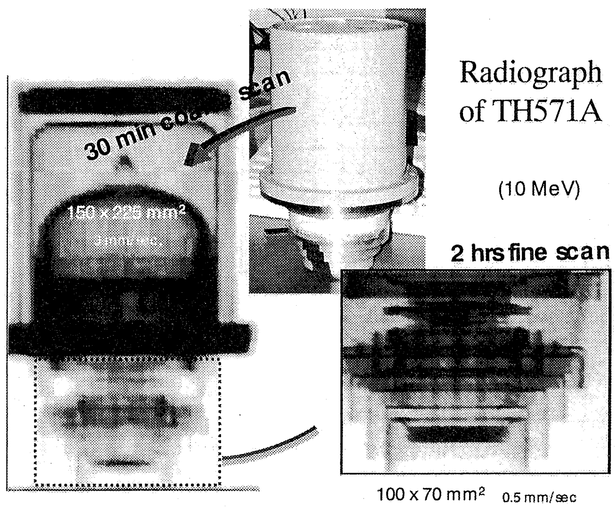

Figure 5: Photograph and transmission type radiographs of RF tetrode TH571A.

Figure 3 shows the dependence of the cavity volume and dielectric constant upon the low-frequency (LF) power. The figure indicates that the LF power makes the cavity volume smaller; i.e., the LF power compresses the film structure. As a result, the dielectric constant increases. This means that we can control the dielectric constant by adjusting LF power in PECVD processes.

2.2 Laser-Compton Backscattered Photons

Figure 4 shows the plan view of the storage ring TERAS. A research project to produce monochromatic photon beam through laser-Compton scattering (LCS) processes was started at the position marked as "LCS-1" in Fig. 4 [2]. The facility has been upgraded gradually to generate completely polarized high-energy photons up to ~10^6 photons/s in the energy range of 1 to 40 MeV [3]. At present, the location LCS-1 is dedicated to the high-energy gamma-ray standardization project. Therefore, the experimental area should meet the regulations for ISO 17025 and it became difficult to perform various experiments other than standardization program in the LCS-1 area.

We have constructed a new site labelled as "LCS-3" in Fig. 4 for LCS experiments. Recently, we examine the photon radiography by the use of LCS photons [4]. Figure 5 shows the photograph and transmission-type radiographs of a tetrode TH571A: The tetrode is used to amplify the 172-MHz RF power to accelerate electrons revolving in TERAS. The photon energy was 10 MeV and the scanned area was 100 × 70 mm^2. The radiographs were taken with two different scanning speeds. The preliminary experiments prove that the LCS photon radiography is really applicable to observe inside of opaque materials.

2.3 Free Electron Laser Research

As previously reported, the compact storage ring NIJI-IV solely dedicated to the FEL research has been improved by installing sextupole-quadrupole-sextupole magnets in all of the short straight sections and by

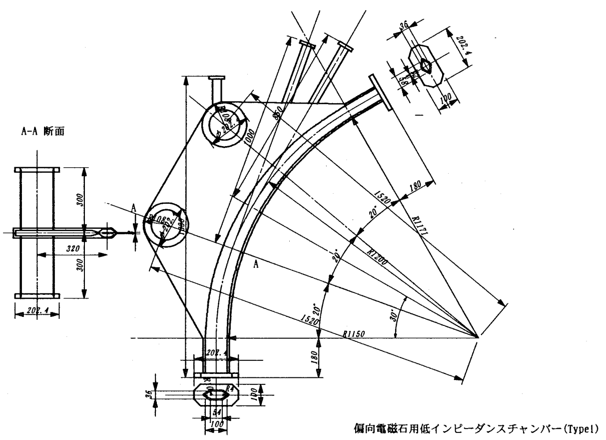

Figure 6: Preliminary design of low impedance vacuum chamber at bending magnets for NIJI-IV.

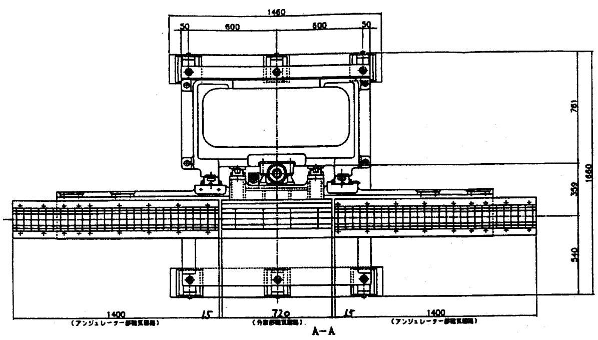

Figure 7: Drawing of upper half of optical klystron for infrared FEL in "FEL-X project."

renewing RF cavity [5]. After that, we renewed the power source of accelerating RF power. Due to the upgrading of the RF system mentioned above, the RF power being fed into the cavity increased from 1 kW to 4 kW; thus the peak electron density in a bunch increased by ~30% than before.

High impedance of the vacuum chamber forming the ring has been remained a serious problem for NIJI-IV, because it results in anomalous bunch lengthening through longitudinal RF instability. Very recently, we replaced vacuum chambers with low impedance ones except for those at the optical klystron and at the septum magnet. Figure 6 shows an example of low impedance chamber to be inserted at six bending magnets; the fabricated one was slightly modified. A calculation tells us that the FEL gain increases more than 10% with the average electron current stored in NIJI-IV above 10 mA; which leads us to the vacuum ultraviolet FEL [6].

At present, we have two major projects with NIJI-IV: one is to shorten the FEL wavelength toward 150 nm, or in the vacuum ultraviolet region, and the other is to lase in the infrared region. The latter is named "FEL-X project"; which is expected to be a powerful tool in medical diagnostics, x-ray microscopy, solid-state physics, materials science, and so on. In this project, we plan to generate hard x rays through LCS processes; the source of photons colliding with high-energy electrons is FEL. The x-ray energy is 0.1-1 MeV and the wavelength of the FEL is about 10 μm. Therefore, a new optical klystron was designed. Figure 7 shows the upper half of the klystron whose total length is about 3.7 m [7]. Manufacturing of the klystron is under way.

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