# STATUS OF TELL, TERAS, AND NIJI's AT THE ETL

MIKADO Tomohisa, OHDAIRA Toshiyuki, OHGAKI Hideaki, SEI Norihiro,
SUGIYAMA Suguru, SUZUKI Ryoichi, TOYOKAWA Hiroyuki, YAMADA Kawakatsu,
YAMAZAKI Tetsuo, CHIWAKI Mitsukuni, NOGUCHI Tsutomu, OKABE Shigeo*,
ONUKI Hideo, and SHITOMI Hiroshi
Quantum Radiation Division, Electrotechnical Laboratory, Tsukuba, Ibaraki 305-8568, Japan
* Okabe Keisoku Kogyosho, 1-7-13 Nozawa, Setagaya-ku, Tokyo 154-0003, Japan

*Abstract*

An electron linac TELL of the Electrotechnical Laborato-ry is generally used to produce high-intensity slow-posi-tron beam and to fill three storage rings, viz., TERAS, NIJI-II, and NIJI-IV.

By the use of a novel chopper-buncher system, more than $10^5$ pulses/s of slow positrons having ~150-ps dura-tion are generated. From the time spectra of positron an-nihilation, defect properties at surfaces, near surfaces, or interfaces are investigated for various materials. Further-more, a neat apparatus has been constructed recently for positron-annihilation induced Auger-electron spectrosco-py.

The present group plans to construct a tomography system using a superconducting wiggler installed at TERAS. There exists a facility to produce highly polar-ized beam of ~1–40-MeV photons by Compton back-scattering of laser light with high-energy electrons stored in TERAS. At NIJI-II, variably polarized radiation is ob-tained with an Onuki-type undulator. NIJI-IV is dedicated to the free-electron laser (FEL) research in short wave-length region. A 6.3-m optical klys-tron has been installed at a 7.25-m straight section to obtain FEL oscil-lation in ultraviolet region.

## 1 INTRODUCTION

An electron linac TELL was con-structed at the Electrotechnical Lab-oratory (ETL) in 1980 [1]. Five ex-perimental rooms surround TELL: low-energy experimental room, me-dium-energy experimental room, high-energy experimental room, pion room, and ring room. Figure 1 shows the cut-away view of the Lin-ac and Optics buildings, where TELL and related facility are in-stalled.

TELL is conceptually divided into three accelerator sections; the first four 2-m accelerator structures form the low-energy section, where 60–75-MeV electrons are available; the following four 3-m ones, the medium-energy section, where 140–160-MeV electrons available; and the remaining twelve 3-m ones, the high-energy section, where 300–400-MeV electrons available.

## 2 SLOW-POSITRON RESEARCH FACILITY

The slow-positron research area consists of the low-ene-rgy experimental room and the adjoining room. In this ar-ea, a vast amount of positrons are generated by ~70-MeV electrons hitting a Ta target (an electron-to-positron con-verter). The positrons enter a stack of very thin W foils (a positron moderator) and ~$10^8$/s of slow positrons emerge from the moderator. The slow-positron pulses, whose du-ration is ~1$\mu$s and repetition rate is usually 100 pulses/s, are converted into a quasi-continuous beam by a linear storage section [2]. Finally, the quasi-continuous beam is converted to a pulse train of more than $10^5$ pulses/s of slow positrons having ~150-ps width by a novel time-bunching system [3].

We use the high-intensity and very short pulses of

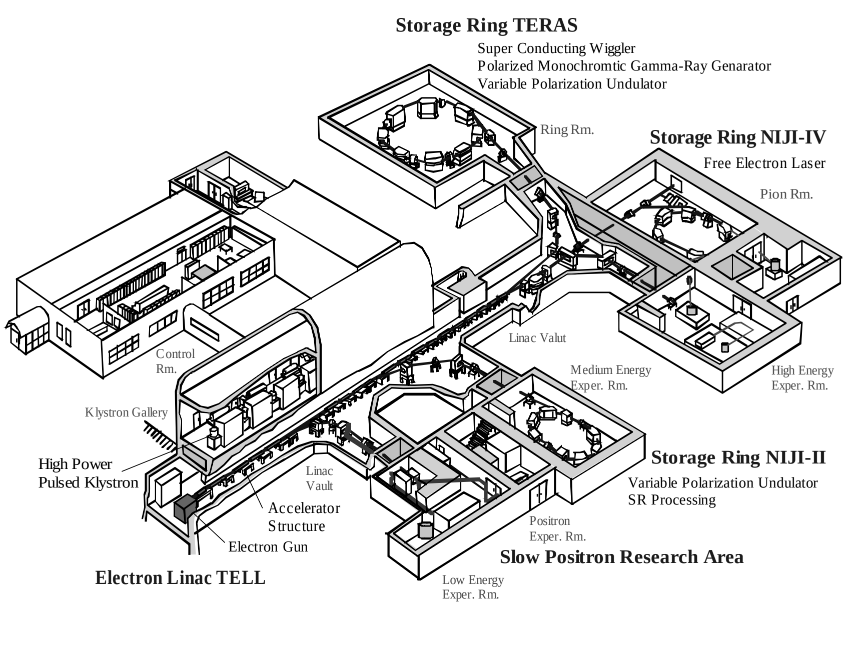


Figure: 1 Schematic layout of the ETL electron accelerator facility.

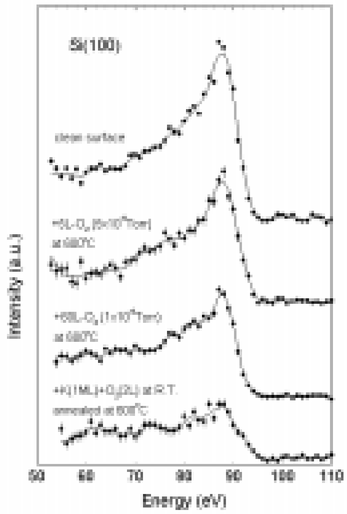


Figure: 2 Energy spectra of positron-annihilation induced Auger electrons. (units L: $10^{-6}$ Torr×s)

slow positrons to study structures of various solid materials or thin films at surfaces, near surfaces, or interfaces by measuring positron lifetime spectra [4]. 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 rates [5]. Figure 2 shows variation of energy spectrum of positron-annihilation induced Auger electrons as a function of amount of $O_2$ exposing to Si(100) surface.

## 3 STORAGE RING TERAS

An electron storage ring TERAS is the first storage ring for ETL which came into operation in 1981 [6]. The electron beam from TELL is usually filled at 300–320 MeV; after the completion of injection procedure, the energy is adjusted to desired values. The shape of TERAS is nearly circular with a circumference of ~31.5 m. At present, the highest energy is 800 MeV and the maximum current is 300 mA for the storage mode. Since its inau-guration, TERAS has been used for research in radio-metric standards, dissociative photoionization, photodis-sociation of sulfur-containing molecules, solid-state phys-ics, x-ray lithography, and so on.

We have also used the electron beam stored in TERAS to construct new types of radiation; for instances, the free-electron lasers (FEL's) in the visible region, the polarized high-energy quasi-monochromatic photons by Compton backscatterings of laser lights. The energy of quasi-monochromatic photons ranges from 1 to 40 MeV by the use of 4-th harmonics of Nd:YLF laser lights. Fig-ure 3 shows energy spectra observed in a polarized-pho-ton scattering experiment. The $1^+$ level of $^{12}C$ at 15.110 MeV is clearly shown by a completely linear-polarized photon beam.

The Onuki-type undulator which can produce varia-bly polarized radiation was originally developed with TERAS [7]. The prototype one is named as PU-1 which realized an idea to generate various types of polarized ra-diation with a single equipment for the first time in the world. A 10-T superconducting wiggler is also

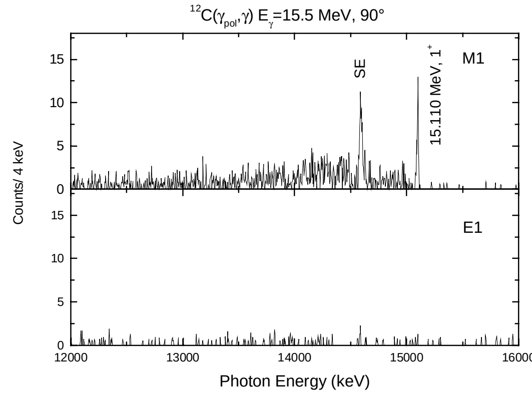


Figure: 3 Energy spectra obtained in a polarized-photon scattering experiment.

installed at 1.8-m straight section of TERAS [8]. We plan to con-struct a computerized tomography system for materials science by the use of intense soft x rays produced with the wiggler.

The FEL study at the ETL was begun with TERAS and the first lasing in visible region was achieved for the first time in Japan [9]. Early in 1991, we succeeded in storing electrons in NIJI-IV being designed as a solely dedicated machine to the FEL study in short wavelengths; thus we moved all the apparatus for FEL experiments to the site where NIJI-IV locates.

## 4 STORAGE RING NIJI-II

In the medium-energy experimental room, there used to be an electron storage ring NIJI-I which was the first compact storage ring in Japan. NIJI-I was constructed in cooperation with Sumitomo Electric Industries, Ltd. (SEI) in 1986. The injection energy ranged from 80 to 180 MeV and the maximum stored current was 0.55 A at 160 MeV. NIJI-I was decomissioned in 1989 with successful achievements for assigned research programs.

After removing NIJI-I, another compact storage ring, named NIJI-II, was constructed in the medium-energy experimental room also as the joint project between the ETL and SEI. NIJI-II is a racetrack-type

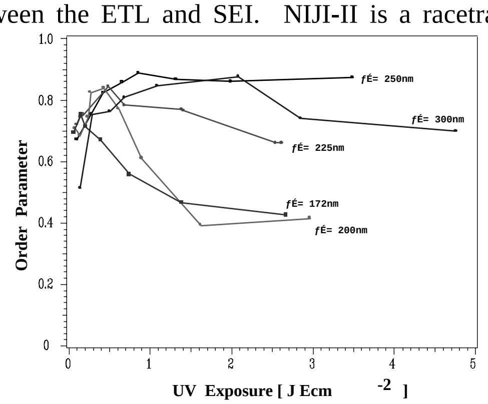


Figure: 4 Degree of uniformity of liquid crystal alignment on the polyimide films irradiated with linearly polarized radiation.

ring with cir-cumference of ~17 m. It has 1.5-m straight sections so that another Onuki-type undulator PU-2 is installed. The overall length of PU-2 is ~1.3 m and the number of peri-ods is 15. The undulator gap varies from 64 to 204 mm and the magnetic field can be modulated mechanically up to 3 Hz.

PU-2 is used for many scientific studies and indus-trial applications. For example, linearly polarized radia-tion has been used for a study of optically-controlled a-lignment of nematic liquid crystal (LC). Recently, LC a-lignment properties on photo-exposed polyimide films have been examined. The LC alignment direction and uniformity depend on the chemical structure of polyimides and ultraviolet (UV) exposure conditions. Figure 4 indi-cates the degree of uniformity of LC alignment on the pol-yimide films being irradiated with linearly polarized UV radiation. These results show that shorter wavelength ra-diation is effective in the LC alignment of polyimide films.

## 5 STORAGE RING NIJI-IV

The commissioning of an electron storage ring NIJI-IV dedicated to the FEL experiment was started at the end of 1990 in cooperation with Kawasaki Heavy Industries, Ltd. (KHI). The first lasing at ~590 nm was observed in Au-gust 1992. Thereafter, we have made many works to im-prove the performance of NIJI-IV. We also studied how to restore optical mirrors being degraded caused by x-ray exposure and surface contamination by residual gases. The surface conditions of mirrors are examined with measuring lifetime of slow positrons or energy distribution of γ rays produced by positron annihilation. We even adopt the positron-annihilation induced Auger electron spectroscopy to investigate mirror surface.

We are very happy to report that the lasing at around 300 nm was achieved very recently with 309-MeV electrons. The key issue was the quality of electron beam; We succeeded in suppressing the head-tail instability by the use of sextupole-magnet sets, and then the peak current increased. Further information is given in the presentation 6D022 by Sei *et al*. at this conference.

The present authors plan to study generation of high- intensity high-energy photons by Compton backscattering of FEL with electrons stored in the ring; the electrons themselves generate FEL. Figure 5 shows the schematic layout of experimental setup arranged preliminarily and estimated brightness of output photons.

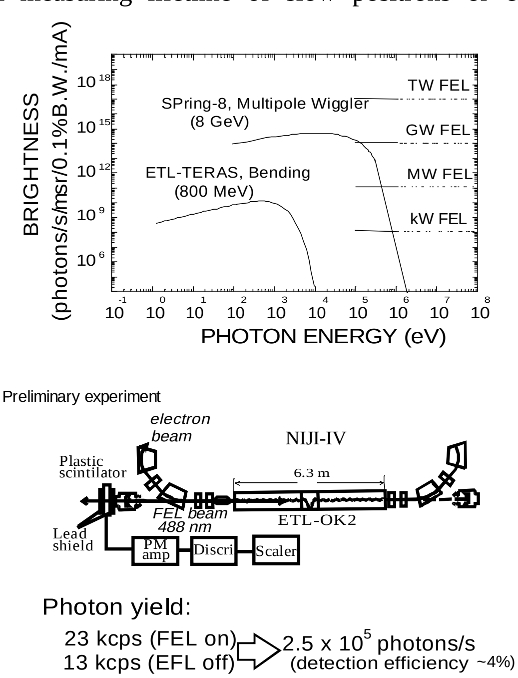


Figure: 5 Experimental setup to generate intense high-energy photons by the use of intra-cavity FEL output.

## 6 ACKNOWLEDGMENTS

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