

## JAPAN TRIP—OCTOBER 9–19, 1999

J. Clendenin

### 1. Tokai. Oct. 11.

I arrived in Tokai on Sunday evening, Oct. 10. On Monday, Oct. 11, a national sports holiday, I visited the Nuclear Engineering Research Laboratory (NERL) in Tokai. It is part of the University of Tokyo, but located on the coast about 200 km north of Tokyo. The Lab is run by Professor M. Uesaka, whom I first met at CERN in 1996, where he gave a very impressive talk on magnetic compression of 20 MeV electron beams. The Lab has installed a twin linac system, which just means there are two linacs side by side. The first, older linac, has a thermionic gun and rf bunching system, two S-band accelerating sections, and finally a bending magnet that doubles as a magnetic compressor and as an energy analyzer. The linac can produce 10-ps pulses that can be compressed to the sub-ps level, or used as is for straight-ahead experiments. The newer linac has an S-band rf gun of the SLAC/BNL/UCLA 1.6-cell type. It uses a Cu cathode. There is only 1 accelerating section followed by a chicane-type magnetic compressor. Gun pulses of several ps have been compressed to <100 fs. Recently the two old low-power klystrons have been replaced by a single higher-power klystron, which has considerably improved the beam phase stability. Presently a plasma acceleration experiment is being put together that will use a plasma cathode and a single external laser but will not use the linacs. The Lab has a considerable assortment of surface analysis equipment primarily for analysis of target changes and/or damage.

### 2. Tokyo. Oct. 12-15.

I participated in the *International Symposium on New Visions in Laser-Beam Interactions* held at Tokyo Metropolitan University (TMU), newly relocated to the western edge of the city. There were 81 participants including 35 from foreign countries (USA, Russia, Germany, Italy, Korea, P.R. China, and Ukraine). There were 35 talks and 15 posters. The Symposium was sponsored by TMU and KEK. Laser-beam interactions is a growing, exciting area of physics driven by new and continuing rapid advances in both lasers and particle beams. Topics covered included:

- < Lasers, including advances in laser energy, stability, and time structure;
- > Particle sources, including emittance preservation, polarized electrons and positrons;
- fi Proposals for new facilities, some large, including a  $\gamma$ - $\gamma$  collider, some modest, as for proof-of-principle experiments or for practical diagnostic applications;
- fl Reports on existing facilities such as the ATF at KEK;
  - New ideas and elaboration of existing ideas for production of  $\gamma$ -rays and X-rays;
  - New techniques; and
  - † Reviews of major areas of relevant theoretical and experimental research.

Of particular interest to me was the talk by Prof. T. Horose of TMU (who was also the Chairman of the Symposium) on “Polarized Positron Source for Future Linear Colliders.”

Among other things, this talk discussed the Compton-backscattering source experiments planned for KEK and BNL. On a similar note, Prof. T. Nakanishi of Nagoya gave an excellent review of "Polarized Electron Sources for Linear Colliders." In the area of low emittance beams from rf photoinjectors, Dr. X. Wang of BNL gave an excellent review, while my talk was on "Reduction of the thermal emittance of rf guns." There were a number of presentations that discussed timing stability issues, including an interesting presentation by Dr. K. Kobayashi of Femtosecond Technology Research Association (FTRA). Dr. A. Endo, also of FTRA, gave an excellent summary of the project to develop a highly-stabilized femtosecond Ti:sapphire laser system for beam-interaction experiments.

I chaired one of the oral sessions, and also gave the concluding remarks.

### 3. Nagoya University. Oct. 16-19.

a) NPES-2 (Nagoya Polarized Electron Source). Dr. Togawa showed me the NPES-2 system. This is a well-built gun and Mott system that replaced the old "homemade" NPES-1 system beginning about 1985. There is no load-lock. The gun can operate at up to 100 kV bias, but usually 70 kV is used. The electrode spacing is 4 cm. The gun design looks similar to the SLC gun. The electrodes are 316 SST (no special manufacturing process). They were prepared in industry by the electropolishing technique developed at Nagoya and sent to Nagoya in an N<sub>2</sub> atmosphere.

b) Dark current problem. The NPES-2 gun operated well for several years, then began to have HV breakdown problems. Following some rather aggressive HV processing, the electrodes appeared to be pitted. (The cathode stalk is relatively easy to remove in order to examine the cathode electrode. The anode electrode can then be viewed from the rear of the HV insulator.) A new cathode electrode was installed. Before cesiating, it processed to 70 kV normally, dark current < 1 nA. However, after cesiating there was again HV breakdown. This whole process was repeated again, so now the gun has its 3<sup>rd</sup> set of electrodes installed. Factors affecting dark current: 1) There is a nanoammeter at the HV terminal for monitoring the dark current. 2) To counter the humid atmosphere in Nagoya, the gun insulator is surrounded with a can containing dry N<sub>2</sub>. (There is a window in the can to read the nanoammeter.) 3) In addition the insulator has a special glass coating to reduce moisture. 4) The gun is pumped by a 150 l/s ion pump and a 150 l/s NEG pump. 5) A Japanese made leak valve is used as an O<sub>2</sub> source. (NPES-1 used a heated silver tube.) 6) SAES channel cesiators are used. These have been changed with each of the electrode changes. All the cesiators are from the same can (shipment) from SAES. The cesiators are typically operated at 4.5 A for 10 min. to activate a cathode. The cesiator has 2 channels operated in parallel. They are retracted after a cesiation. 7) The pressure is measured with a nude ion gauge. 8) Typical pressures are  $2 \times 10^{-11}$  Torr. 9) The gun is baked at 200-250 °C for 50-100 h. 10) There is a resistive heater that fits into the atmospheric side of the tube that holds the crystal, similar to the SLC gun technique. The heater is operated in a static N<sub>2</sub> atmosphere. The monitoring TC is on the vacuum side. The last 10 cm of the crystal holder is Mo. The As-capped SL crystals are only heat-cleaned to 400 °C. My conclusions: the electrode cleaning and assembly process is probably not the problem since 3 iterations over several years produced the same results. A more likely candidate is that the channel cesiators are defective and release some contaminants.

The Mott polarimeter has 80 nm Au foils and Si detectors. The Wien filter operates at 70 kV.

c) NPES-3. Wada showed me the NPES-3 project. It will consist of a 200-kV gun with loadlock.

The load-lock and activation chamber is essentially complete. It contains an H<sub>2</sub> dissociation tube for hydrogen cleaning in the style developed at TJNAF. The cathode puck is heat-cleaned by an induction coil in the style of the system developed for the SLAC inverted-structure gun.

The gun HV insulator has about 10 segments, with the middle one being at 200 kV, with 100-k $\Omega$  resistors between each segment to eventual ground at each end. This is similar to the NIKHEF gun designed (and built) at BINP. The cathode-anode spacing is about 3 cm. The electrode design is for 3 MV/m at  $r=0$  and 200 kV and a maximum field of about 8 MV/m, which occurs at about  $r=3$  cm. The gun is designed to produce 30 A peak current pulses. Since there is a large current to ground through the insulator resistors, a different way to monitor the dark current had to be found. The present plan is to put the nanoammeter across the last ceramic segment to ground on the electron beam side. The return to the HV PS is then slightly above ground. A similar break has to be made at the ground side on the load-lock end. The gun uses a cathode puck, which is locked into place with a unique design.

The first attempt to braze the ceramic assembly failed. There was some redesign to eliminate problems of thermal expansion. The second attempt to braze with a new ceramic assembly was successful.

d) RF gun for unpolarized electrons. Furuta is working on an S-band rf gun project. This work is in cooperation with SPRING-8. The electron beam will be used for Compton backscattering experiments, etc., but not for polarized electrons. A Cs<sub>2</sub>Te cathode will be used, the first such combination in Japan. Initial testing will be done at Nagoya with a low-power rf source. The source preparation chamber and load-lock is essentially complete. The old 1-cell rf gun from KEK is available to begin the testing. Later a new gun will be built. Ms Sugiyama, a student of Prof. H. Kobayakawa, is also working on this project.

e) RF gun for polarized electrons. A version of CERN Gun V is being built. The rf design of this gun was done at CERN. The idea is to use special materials and assembly techniques to reduce the dark current so that the gun may also be used for testing an activated GaAs cathode. A cold test version has been fabricated from Al. The surface inside the cavity has been measured and found to have errors in places as much as 0.050 mm. This type of error can in principle be eliminated in the final version. The motivation to finish this gun is somewhat reduced since Gun IV is working quite well at CERN and since there is more concern now about increasing the pumping speed. At this time Nakanishi seems not to have a good idea how to increase the pumping speed.

f) Seminar. On 10/18 I gave an informal physics seminar on "Polarized electrons at SLAC."

g) HV test apparatus (at KEK). This apparatus was used for Suzuki's thesis: dark current studies. It is being modified to permit dark current studies of a GaAs crystal. The goal is to separate the dark current of the crystal holder from that of the crystal itself.

h) Laser system. Dr. Togawa showed me the laser system. It consists of a Spectra Physics Quanta Ray YAG pumping a Quanta Ray Ti:sapphire laser tuned to the appropriate semiconductor band gap. About 3 mJ is produced at 10 Hz. This is attenuated, then chopped by a Lasermetrics Pockels cell driven by a fast Kentech pulser to generate a 0.7 ps pulse with a risetime of 100 ps. The pulse is split, the second pulse delayed by fixed 2.8 ns. A fibre optic cable takes the laser light to the gun. At the cathode, each pulse is about 3

$\mu\text{J}$ . Next a variable delay will be installed. This requires the pulse tails to be cleaned up, which will be done by using additional pulsed Pockels cells.

i) PES Satellite Workshop, Oct. 12-14, 2000.

This is the traditional workshop preceding the H.E. Spin Symposium. Prof. C. Prescott of SLAC is the chairman of the International Committee. The Symposium will be held in Osaka, Oct. 16-21, 2000. Nakanishi is proposing to organize the satellite workshop in the Nagoya area. He has asked me to be on the advisory board as I was for the 1998 satellite workshop in St. Petersburg. We are planning for ~50 participants. The location will probably be in a local mountain resort region easily accessible by train. By tradition we will try to attract scientists from a wide variety of disciplines, united by a common interest in producing polarized electrons. Fees and publication of the proceedings will be coordinated with the Symposium Local Organizing Committee. Nakanishi will seek the support of Nagoya University and KEK, especially to help bring Russian scientists to the Workshop.

j) I spent several hours with Suzuki reviewing the draft of his journal paper describing the dark current measurements. (See g) above.) I commented that the presence of  $\text{Cu}(\text{OH})_2$  on the surface of the electropolished cathode is a strong candidate for the source of the dark-current generating ions, but in fact he had not actually demonstrated this to be the case. Also it seems to me that the field emission data for DT+OUR is anomalous.

Otherwise, the data points to diamond turning (DT) + pure water rinsing as the best preparation technique, resulting in  $\beta \sim 50$  independent of gap. We noted that the rf cavity tested at KEK (see, for example, M. Yoshioka et al., Proc. of the 1994 Int. Linac Conf., Tsukuba, Japan, 1994, p. 302) was prepared in a similar manner, but had slightly better performance:  $\beta \sim 30$  and dark current turning on at higher fields. This may be due to the difference between dc and rf fields.

How can  $\beta$  be reduced and the field increased? Nakanishi believes the surface roughness has no effect on the dark current. The scratch depth is  $0.05 \mu\text{m}$ , which is state-of-the art, but no dark-current measurements have been made for larger values. Likewise, it is noted that Yoshioka et al. used high pressure water rinsing while Suzuki used only high purity water rinsing.

## LITERATURE ACQUIRED

### Preprints and reprints:

UESAKA xx. M. Uesaka, T. Watanabe, H. Harano, K. Kinoshita, J. Sugahara, T. Ueda, K. Yoshii, K. Nakajima, A. Ogata, F. Sakai, M. Kando, H. Kotaki, H. Dewa, and S. Kondo, "Femtosecond quantum beam science and new pump-and-probe analysis," *Femtosecond Quantum Beam Science* (19??) 313.

Good summary of the NERL twin-linac capabilities.

UESAKA 97. M. Uesaka, T. Watanabe, T. Ueda, M. Kando, K. Nakajima, H. Kotaki, a. Ogata, "Production and utilization of synchronized femtosecond electron and laser single pulses," *J. of Nucl. Mat.* 248 (1997) 380.

Applications: 1) Laser wakefield acceleration; and 2) "Pulse-snapshot" X-ray diffraction.

HARANO 98. H. Harano, K. Kinoshita, T. Watanabe, K. Yoshii, T. Ueda, and M. Uesaka, "Fundamental research of subpicosecond time resolved X-ray diffractometry using electron linac," EPAC98.

Applications: X-ray diffractometry.

SUGAHARA 98. J. Sugahara, K. Yoshii, M. Uesaka, T. Ueda, T. Watanabe, Y. Shibata, "Diagnostics of subpicosecond electron beam by Michelson interferometer and femtosecond streak camera," EPAC98.

Same as second half of UESEKA 98a.

UESAKA 98a. M. Uesaka, K. Kinoshita, T. Watanabe, T. Ueda, K. Yoshii, H. Harano, J. Sugahara, K. Nakajima, A. Ogata, F. Sakai, H. Dewa, M. Kando, H. Kotaki, and S. Kondo, "Femtosecond electron beam generation by S-band laser photocathode rf gun and linac," AAC98.

1.6-cell S-band rf gun built by BNL/KEK/Sumitomo installed in 2<sup>nd</sup> twin linac. Cu cathode with  $QE \sim 10^{-4}$ . RF 100 MV/m, 4-8  $\mu$ s, 10-ps FWHM. With 75- $\mu$ J quadrupoled YLF (263 nm) laser, get 2 nC, beam diameter 3 mm, energy 3.5 MeV. Accelerate to 17 MeV.  $\epsilon_{n,rms} \sim 3 \times 10^{-6} \pi$  m.

Using chicane-type compressor, compress 13 ps pulse to 440 fs. Good comparison of interferometer with streak camera for 500 fs pulse.

Dark current is 2 nC per 4- $\mu$ s rf pulse. Timing stability is 3.5 ps.

Lots of charge lost in chicane.

UESAKA 98b. H. Harano, K. Kinoshita, T. Ueda, M. Uesaka, T. Watanabe, K. Yoshii, H. Dewa, M. Kando, H. Kotaki, S. Kondo, f. Sakai, K. Nakajima, H. Nakanishi, A. Ogata, A. Endo, M. Washio, "Femtosecond electron beam generation by S-band laser photocathode rf gun and linac," EPAC98.

Same as first half of UESAKA 98a.

KASHIWAGI 99. S. Kashiwagi, M. Washio, T. Kobuki, R. Kuroda, I. Ben-Zvi, I. Pogorelsky, K. Kutsche, J. Skaritka, V. Yakimenko, X.J. Wang, T. Hirose, T. Muto, K. Dobashi, J. Urakawa, T. Omori, T. Okkugi, A. Tsunemi, D. Clilne, Y. Liu, P. He, and Z. Segalov, "Observation of High Intensity X-rays in inverse Compton scattering experiment," draft of preprint to be submitted to Int. Sym. on Laser-Beam Interactions, Tokyo Metropolitan Univ., Oct. 1999.

TOGAWA 99. K. Togawa, T. Nakanishi, T. Baba, F. Furuta, H. Horinaka, Y. Kurihara, H. Matsumoto, T. Matsuyama, T. Nishitani, S. Okumi, T. Omori, C. Suzuki, Y. Takeuchi, K. Wada, K. Wada, M. Yamamoto, and M. Yoshioka, "Production of polarized electron beam with sub-nanosecond multi-bunch structure from superlattice photocathode," preprint, submitted to Int. Sym. on Laser-Beam Interactions, Tokyo Metropolitan Univ., Oct. 1999.

NAKANISHI 99. T. Nakanishi, K. Togawa, T. Baba, F. Furuta, H. Horinaka, T. Kato, Y. Kurihara, H. Matsumoto, T. Matsuyama, T. Nishitani, S. Okumi, T. Omori, T. Saka, C. Suzuki, Y. Takeuchi, K. Wada, K. Wada, M. Yamamoto, and M. Yoshioka, "Polarized electron source for a linear collider in Japan," preprint, submitted to Int. Sym. on Laser-Beam Interactions, Tokyo Metropolitan Univ., Oct. 1999.

**In addition, the following literature was acquired:**

"Joint Research Project for Laser Wakefield Acceleration" and Subpicosecond Twin Linac System," reduced size posters from NERL.

NREL brochure outlining research programs (in Japanese).

Tokyo Metropolitan University Bulletin 1998-1999 (in English).

Summary of Suzuki's work on dark current, 8 pages (mostly figures).

Three figures for NPES-3: 1) Cross section of gun with activation chamber; 2) Electrode design including calculated fields; and 3) View of load-lock and activation chamber.