# U.S.-to-Japan Exchanges in HIF


John J. Barnard


US-Japan Workshop

June 10-12, 2004

Princeton, NJ

# Recent US exchanges to Japan have taken place at six institutions

RIKEN

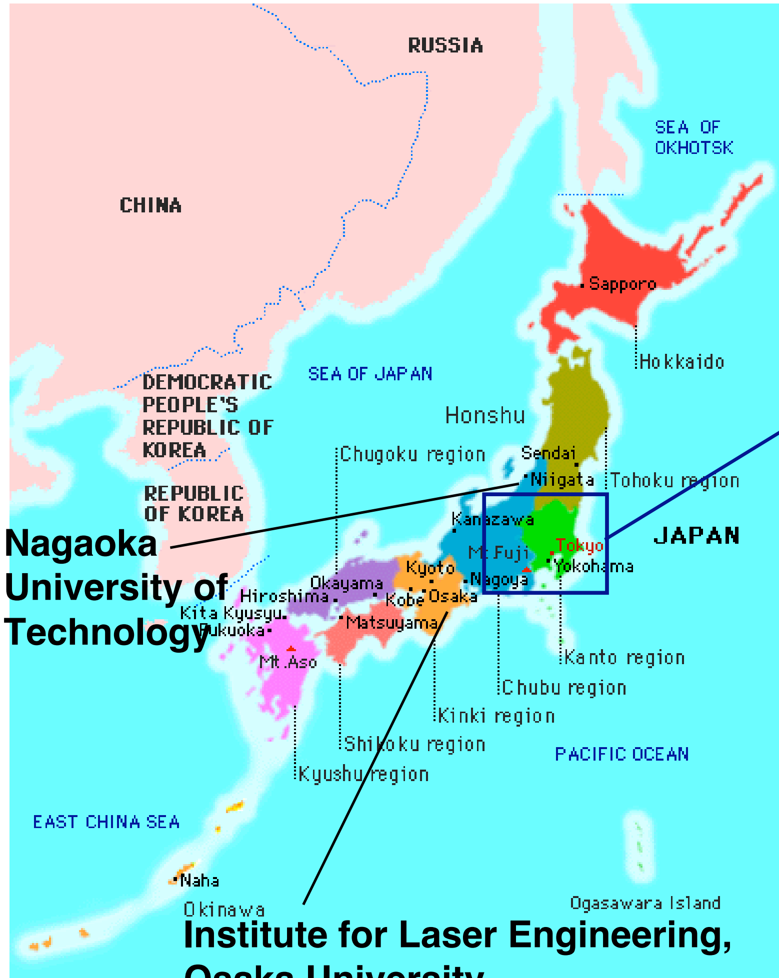
Utsunomiya University

Tokyo Institute of Technology-Ookayama and Suzukakedai Campuses

KEK

JAERI-Naka

# Location of institutions in Japan





# US/Japan collaboration on HIF began with a series of workshops: primarily information exchanges

| | |
|---|---|
| March 13-15, 1997 | Osaka |
| November 12-14, 1997 | Berkeley |
| December 7-9, 1998 | Tokyo |
| March 11, 2000 | San Diego |
| December 7-8, 2000 | Tokyo |
| March 4-5, 2002 | Berkeley, Livermore |
| June 10-12, 2004 | Princeton |

# US-to-Japan Exchanges (2001-2002)

**Ion Source Development (October 13, 2001- October 26, 2001)**

**J. Kwan -> M. Ogawa, Tokyo Institute of Technology, JAERI**

- **Laser based ion sources**
- **Collaborated on an experiment using a controlled extraction grid to measure rise time of a short beam pulse (~200 ns) relevant to IBX**
- **work contributed to publication: ( J. Hasegawa; M. Yoshida; M. Ogawa; Y. Oguri1; M. Nakajima; K. Horioka; J. Kwan, "Influence of Grid Control on Beam Quality in Laser Ion Source Generating High-Current Low-Charged Copper Ions",(IFSA2003).**

**Theory and Modeling of Space-Charge Effects (February 18-22, 2001)**

**J. Barnard/S. Lund -> T. Yabe (TIT), T. Katayama, (RIKEN), S. Kawata, (Utsunomiya), T. Horioka (TIT), M. Ikegami, S. Machida(KEK)**

- **Made/heard presentations and had fruitful discussions at all 5 institutions; Topics included: WARP, HERMES, bunch compression in rings and linacs, emittance growth; CIP method, dielectric wall neutralization, compact bunch compressor, FFAG accelarators, halos....**

# US-to-Japan Exchanges (2002-2003)

Workshop on Induction Accelerators and Their Applications, October 29-31, 2002, at KEK (organized by T. Horioka and K. Takayama) J. Barnard, M. Leitner, W. Waldron from VNL (G. Caporaso, Y-J. Chen, E. Cook from LLNL, R. J. Briggs, SAIC)

- heard presentation on varied uses and technology advances in induction accelerators, including induction synchrotron
- began collaboration on a book on induction accelerators (now in progress)

Theory and Modeling of Space-Charge Effects, March 10 - 13, 2003, H. Qin, D. Grote -> S. Kawata (Utsunomiya), T. Horioka, M. Ogawa (TIT), T. Katayama (RIKEN)

-had fruitful discussions on beam dynamics and numerical simulations at all three institutions.

# Summary of induction accelerator architectures

| Architecture | Focusing | Advantages | Remarks |
|---|---|---|---|
| Linacs: | | | |
| Induction Linac ($e^-$) | Solenoid | High peak power; High efficiency; | |
| Induction Linac ($HI^+$) | Quads | High peak power; Longit. compress. | |
| Dielectric Wall Accel. | Magnetic/ Electrostatic | Very high gradient | <~ few 100 ns early dev. |
| Rings: | | | |
| Induction Synchrotron | Quads | Current const. over super bunch; Higher luminosity | |
| Induction barrier bucket | Quads | Highly flexible waveform shape; | DARHT kicker POP for modul. |
| Induction buncher | Quads | | |
| Induction FFAG | FFAG | Compact, low cost; | Larger phase sp. |
| Induction recirculator | Quads (static) | Low cost; | Vacuum; Dipole losses; Resonance trav. |

# Summary of applications for induction accelerators

| Application/ Architechture | Voltage | Beam Current | Pulse length | Rep. rate | Issues/comments |
|---|---|---|---|---|---|
| Hadron collider/ $p^+$ ind. synchrotron | 31 TeV; 3 MeV/turn | 25 A | 500 ns | 100 kHz CW | feasibility study going on; require upgrade of most existing detector components for higher L. competitor: low harmonic rf |
| RK Two Beam Acc for Linear Colliders/$e^-$ ind. linac | 10 MeV, 0.3 MeV/m | 1 kA | 50 - 200 ns | 180 Hz | fundamental aspect has been demonstrated; no current funding |
| Neutrino factory;□-collider / □ □ind. linac | 200 MeV 2 MeV/m | | 100 ns | 4 pulse @ 3 MHz; 15 Hz avg. | feasibility study going on; competition with low freq rf device; can survive rad. env.; |
| Heavy Ion Fusion/ $HI^+$ ind. linac | 4 GeV 1.5 MeV/m | 0.2 - 10 kA | 20 □s - 10 ns | ~6 Hz | Significant program ongoing |

# Summary of applications for induction accel's-cont'd

| Application/ Architechture | Voltage | Beam Current | Pulse length | Rep. rate | Issues/comments |
|---|---|---|---|---|---|
| Spallation n-source/ $p^+$ ind. linac | 1 GeV | 60 - 100 A | 1600 - 160 ns | 50 Hz | Will be easier to sell if induction technology more widespread |
| Radiography/ $e^-$ ind. linac | 18.4 MeV | 2-4 kA | ~50 ns | ~2 MHz bursts of 4 pulses | DARHT-II built and undergoing testing. Ion-hose, beam-target interactions AHF to use protons/synch. |
| Sub-critical reactor/ ind. FFAG; H- driver for spallation n-source; Accel. Trans. Waste (H- ind. FFAG) | ~ 1 GeV 1-3 GeV | 30 mA 10 mA (avg) | ~few 100 ns | 1 kHz CW | May combine rf + ind.(Ind barrier only); cost/MW beam power is low rel. to rf linac; early design, at idea stage |
| Driver for Microwave source FEL's, BWO | ~few MeV | ~kA | ~few 100 ns | ~kHz | Very attractive match |

# US-to-Japan Exchanges (2003-2004)

**Space charge and dispersive effects in the bunch compression of a heavy ion beam in a ring, S. Lund-> T. Katayama, T. Kikuchi, (RIKEN), M. Ogawa, (TIT )**

- Collaborated with Dr. Kikuchi to implement WARP code on beam dynamics problems at RIKEN
- Collaborated with Dr. Katayama, on effects of space charge and dispersion during bunch compression, with goal of optimizing design of future bunching rings at RIKEN, with possible HEDP applications

**Multielectron Losses Due to Heavy Ion – Atom Collisions/ Negative Ions May 17 - 21, 2004, L. Grisham -> Dr. Nakagawa (RIKEN) and Y. Oguri (TIT)**

- Looked at feasibility of using RILAC at RIKEN to accelerate singly charged negative ions and measure cross-section for neutralization (Hope to use similar ion of positive charge for direct comparisons)

# The state of the US-Japan collaboration

US-Japan researchers are part of a small but well integrated community; Professional relationships across the Pacific are being developed.

Informational exchanges have been tangible, and collaborations have started to develop.

Areas of potential collaboration include:

- Induction modulator and induction core material research
- Bunch compression in rings and linacs
- Final focus using using a plasma lens or solenoids as the final optic
- Neutralization during final focus
- Vlasov modeling of beams using PIC and a direct, semi-Lagrangian CIP method; (Fluid simulations in chamber may also benefit from codes using CIP method).
- Source and injector physics and technology
- Negative ion cross-section measurements
- High Energy Density Physics

Both countries benefit politically from the involvement in each other's program.