FusionCanada

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Canada-Japan Agreement

Canada and Japan have agreed on a renewal of cooperation and collaboration activities linking Canadian and Japanese fusion programs. Representatives from the Japan Atomic Energy Research Institute (JAERI) and Atomic Energy of Canada Limited (AECL) are named as signatories to a Memorandum of Understanding on the subject, which describes the areas of mutually agreed cooperation and collaboration during the renewal period, which lasts until March 31, 1989.

The cooperation and collaboration agreement was originally made between JAERI and the National Research Council of Canada, who at the time had responsibility for the National Fusion Program.

The technical areas named in the Memorandum are (1) tritium technology, (2) tokamak research, and (3) other research and technology areas (to be later defined) which are recognised as being of mutual benefit.

Tritium Technology. Topics include fusion fuels systems, breeder blanket technology as well as safety and environmental studies.

Tokamak Research. Topics include confinement physics, auxiliary heating, current drive and plasma refuelling. Technology topics include advanced diagnostics and data acquisition and control systems.

For Japan, the named signatory is Dr. K. Tomabechi, Director General of Naka Fusion Research Establishment. Dr. David Jackson, Director—National Fusion Program, is the named signatory for AECL.

Tokamak Inauguration

Tokamak de Varennes was inaugurated jointly by Marcel Masse, Federal Minister for Energy, Mines and Resources, (centre) and Guy Coulombe, President and CEO of Hydro-Québec (right) on June 17, 1987. Tokamak Director Richard Bolton observes from left.

Many dignitaries enjoyed the ceremony, attending from federal and provincial departments and agencies involved in fusion development, and from Canadian and foreign fusion centres.

Four Canadian centres engage in ICF-related laser-plasma research. 'Fusion-Canada' will introduce them individually.

University of Alberta and The ALTECH Project

Edmonton, Alberta

The University of Alberta pursues a broadly based program of laser-plasma research, motivated by the needs of ICF. Current emphasis is on quarter-micron Krypton Fluoride (KrF) laser-plasma research, conducted by the Electrical Engineering Department (Laser-Plasma Research Laboratory) and the Physics Department. Over the past 20 years U of A has actively contributed to:

- high power CO_2 and KrF laser development,
- experimental laser-plasma interaction studies,
- theory and numerical simulation,
- diagnostics development.

The group also continues fundamental studies on CO_2 laser-plasma interaction.

The success of this program and the importance of excimer lasers have led to the ALTECH Project, a joint industry-university undertaking to establish a national centre for high power KrF laser development and ICF research.

The programs are being enhanced through working agreements with Lawrence Livermore National Laboratory and Los Alamos National Laboratory (USA) and with the Institute of Laser Engineering in Osaka, Japan.

Laser Development.

Researchers have designed and built a short pulse KrF laser for target irradiation experiments at intensities up to 10^{14} watts/cm^2. The laser has four discharge modules and an electron beam pumped amplifier. Optical beam multiplexing and nonlinear Brillouin pulse compression produce a 2 nanosecond output pulse from a 60 nanosecond pump pulse. KrF laser development began in 1980 with assistance from LLNL. An important goal is to develop capabilities for building high power, variable pulse length KrF lasers. Improvements in Brillouin pulse compression and KrF electron beam pumped amplifier efficiency are two of the many development topics. *(Contact Prof. A.A. Offenberger, Elec. Eng.)*

Theoretical Work.

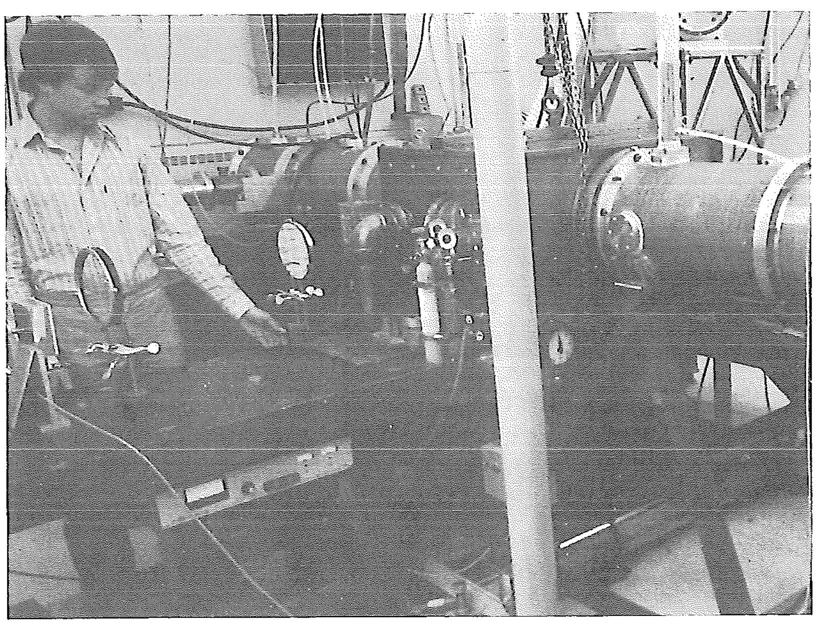
Important study topics include turbulence and energy transport in dense, strongly coupled plasmas (in which Coulomb effects dominate particle behaviour). Coupling between stimulated Raman scattering and stimulated Brillouin scattering is a problem of particular interest. Analytical and numerical simulation studies of the coupled equations are being pursued; highly localized intense electric fields and density cavities are observed which give rise to strong turbulence effects and particle heating. *(Contact W. Rozmus, Physics).*

Numerical Modelling.

This group has special interests in modelling short wavelength laser beam propagation in plasmas, and X ray and electron thermal energy transport. One-dimensional (1-D) and two-dimensional (2-D) codes have been developed for these and other studies. X ray generation and radiation transport for higher atomic weight materials have been incorporated in a 1-D code (originally developed from the MEDUSA code) for simulating KrF laser-target experiments. The 2-D code, developed from the CASTOR code, incorporates an ionization model to correctly simulate plasma evolution in irradiated cold targets. This code can model laser beam propagation, including beam diffraction, refraction and attenuation. *(Contact C.E. Capjack, Elec. Eng.)*

Experimental Work.

Currently, the emphasis of the KrF laser-target experiments is on measuring ablation parameters, characterizing X ray emission from various elements and investigating parametric instabilities at quarter-micron wavelengths. Intensity scaling measurements of mass ablation rates and ablation pressure have been made. Quantitative X ray conversion measurements have been made for many elements (low to high atomic number). Detailed spectral analysis of X ray emissions from these targets has begun. Parametric instabilities such as Brillouin scattering are also being studied. Current developments in diagnostics include a short pulse probe laser (less than 100 picoseconds) for studying the evolution of target plasma blowoff and a fast response X ray calorimeter for discriminating between prompt X ray emission and plasma ions.
(contact R. Fedoseyevs, Elec. Eng.)



Electron beam pumped amplifier for the U of Alberta KrF laser.

Recent publications include:—

Non-linear evolution of Stimulated Raman Scattering in Homogeneous Plasmas. W. Rozmus, R.P. Sharma, J.C. Sampson and W. Tighe. Physics of Fluids, Vol 30, p. 2181, 1987.

Subnanosecond Pulses from a KrF Laser Pumped SF_6 Brillouin Amplifier. R. Fedoseyevs and A.A. Offenberger. IEEE Journal Quantum Electron., QE-21, p. 1558, 1985.

Measurement of KrF laser/plasma X ray Radiation from Targets with Various Atomic Numbers. R. Popil, W.P. Gupta, R. Fedoseyevs and A.A. Offenberger. Physics Review A35, p. 3874, 1987.

Use of X ray Measurements for Testing Thermal Transport Models. R. Marchand, D. Havazelet, C.E. Capjack A. Birnboim. Physics of Fluids, Vol. 30, No. 2, pp. 510–514, February 1987.

More information, and copies of papers, from named persons. (See Contact Data)

The ALTECH Project.

Director: *Prof. A.A. Offenberger*

The ALTECH Project is a joint undertaking of Alterra Laser Technologies (ALTECH), the University of Alberta and General Systems Research Inc. (GSR) of Edmonton. The Project objective is to develop high power KrF lasers for ICF work and other applications.

Development of a 10 kilojoule short pulse KrF laser system with multibeam architecture is ultimately envisaged. The high energy laser will be used for direct drive spherical target compression studies. Design and development work is currently in progress. Lawrence Livermore National Laboratory has generously loaned a one kilojoule KrF laser amplifier for the ALTECH Project. It will be incorporated into a new facility for planar target irradiation studies, and will ultimately become part of the front end for the planned 10 kilojoule system. A broad program of laser development will be pursued, including such topics as electron beam pumped amplifiers, laser optics and pulse compression by means of beam multiplexing and Brillouin scattering.

The Natural Sciences and Engineering Research Council (NSERC) supports work at University of Alberta. The ALTECH Project was initiated with contributions from the University, ALTECH, and GSR Inc.

TECHNICAL UPDATE

Tokamak de Varennes

Good progress has been made with tokamak commissioning, and with installation of diagnostic equipment. Plasma pulse duration recently reached 0.8 seconds, at the design base toroidal field of 1.5 tesla. Plasma position and current control feedback systems are now operational. Although operation at all design parameters has not yet been attained, present progress is satisfactory. The majority of diagnostic systems are expected to be installed and functional by the end of 1987.

Plasma Conditions.

Control system commissioning and tuning has considerably improved plasma discharge stability and plasma pulse duration. By October 2, plasma pulses of 0.8 seconds had been obtained, with good plasma position control, at a plasma current of 80 kiloamps (about 30 percent of design operating current) and a toroidal field of 1.5 tesla (100 percent of design).

The machine has now fired more than 1250 shots, of which about 800 have been plasma discharge shots. Continued operation and plasma discharge cleaning have lowered plasma impurity levels. Torus loop voltage is now reduced to the expected value of two volts, compared with 6 volts in the first series of plasma discharges. Plasma electron density values (line average) between $5 \times 10^{18}/m^3$ and $1.5 \times 10^{19}/m^3$ have been measured. Target electron density is about $4 \times 10^{19}/m^3$ at full field.

For the first two months of operation, movement of the toroidal field coils during machine pulses was limiting usable magnet operating currents. Minor modifications have rectified the problem, so that the increase to the full toroidal field of 1.5 tesla now causes no further magnet coil movements.

Plasma current regulation is excellent. Plasma current is now controlled via the plasma current feedback system (newly commissioned), which regulates the power supplies feeding the tokamak primary circuit coil so that plasma current follows an operator-selected time/current waveform. The vertical and horizontal plasma position control systems are now operating, and are being adjusted to suit machine characteristics.

Diagnostics

Installation and commissioning progresses well. The systems now mounted include:

- Visible spectroscopy
- Electron cyclotron radiation
- Langmuir probe
- Sub-millimeter laser interferometer (214 micron)
- Microwave interferometer (140 GHz)
- Hard X ray system
- Soft X ray tomography (first detector module).
- TV Cameras

Electron density was measured with the microwave interferometer, which is fully operational. First electron density measurements with the newly installed laser interferometer are in agreement.

Diagnostic systems still being installed include:

- Thompson laser scattering
- Far ultra-violet spectroscopy
- Plasma chamber surface analysis station
- Bolometers

In the coming months, a laser blow-off impurity injection and measurement system and the remaining four X Ray tomography detector arrays will be mounted, as well as other diagnostics.

More information from:

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TEXTOR

Ten Years of international collaboration.

October 6, 1987 marked the tenth anniversary of the TEXTOR tokamak project. On behalf of Canadian fusion workers, the National Fusion Program offers its congratulations to the TEXTOR design and operations team on the success of the project.

Since TEXTOR began operation in 1982, several Canadian workers have had the opportunity to perform experiments and development work on the machine. Their work has contributed significantly to fusion development in Canada; several of the developments have been embodied in the Tokamak de Varennes. The National Fusion Program wishes to thank TEXTOR team members and operations staff for the opportunity to be associated with TEXTOR, and for their unfailing cooperation and courtesy towards visiting Canadians.

Canada was a signatory to the original TEXTOR enabling agreement in 1977. TEXTOR was built at Kernforschungsanlage Jülich (KfA Jülich), Federal Republic of Germany. NFP contributed manpower and equipment during construction and commissioning, and received seven percent of TEXTOR's experimental time after 1982. TEXTOR team members are the European Community, Switzerland, Canada, USA and Japan. Dr. Charles Daughney (NFP Manager for Magnetic Confinement) is Canada's delegate to the TEXTOR Executive Committee, and Dr. E.B. Deksnis (Canatom Inc.) is the alternate delegate.

Canadian workers at TEXTOR have been:

Dr. H. Van Andel, Université de Montréal. During 1983–85, Dr. Van Andel developed a method of measuring plasma turbulence parameters by forward laser beam scattering. The work showed a strong correlation between plasma turbulence and the 'sawtooth' plasma instability which disrupts stability of plasma density and temperature in the core of the tokamak plasma. This is a stimulating contribution to tokamak plasma physics. Dr. Van Andel's experiments measured turbulence wavelengths and frequency spectra.

Dr. James Castracane, MPB Technologies Ltd. (Montreal), developed a method of measuring transport of heavy plasma impurity ions, using a laser-energized impurity injection system. Spectral and spatial measurements of emission lines from the impurity ions provide data on impurity transport and distribution in the plasma. The equipment, developed jointly by MPB and INRS-Energie, has yielded useful data on plasma impurity concentrations, especially in the plasmas which 'detach' from the tokamak limiters. The work began in 1983 and continues in 1987.

Dr. Jean-Marc Larsen, INRS-Energie (Varennes, Québec) continued his work on acquisition and management of experimental data. Dr. Larsen developed a system using dedicated small computers for acquiring data from individual experiments. The system can operate as a stand-alone system, or interact with a central computer system for data archiving and analysis. The Tokamak de Varennes data acquisition system is based upon the TEXTOR design and on much useful collaboration.

Dr. Walter Shmayda, Ontario Hydro Research Division (Toronto), is measuring neutral atomic particle fluxes, using probes with iron membranes. This work began in 1984 and is still in progress.

Dr. Guy Ross, INRS-Energie, investigated plasma-wall interactions, measuring temperature and density profiles in plasma edge regions. His work during 1985–1987 employed a laser blowoff technique to inject lithium and carbon atoms into the plasma. Data indicating the temperature and density profiles was obtained by measuring ionization rates for the injected ions. Ionization rates were measured by analyzing line radiations emitted during the ionization process.

During the construction and commissioning years, 1977–82, contributions included probe drive equipment, and scientific and engineering effort. *Dr. James Robinson*, from UHV Instruments Ltd. developed and supplied the plasma probe drive equipment. *Dr. Ed Deksnis* of Canatom Ltd. assisted in developing high vacuum systems, and performed heat transfer calculations. *Dr. Jean-Marc Larsen* performed early work in developing the experimental data acquisition systems.

The original TEXTOR agreement matured in 1986, and was extended by all parties until 1992. The National Fusion Program wishes continued success to TEXTOR, and looks forward with pleasure to continued collaboration throughout the life of the TEXTOR project.

INDUSTRY IN FUSION

In each issue, FusionCanada will introduce Canadian companies working in fusion development. We begin with one of the companies closely involved with Tokamak de Varennes.

MPB Technologies Inc.

Dorval, Quebec

MPB Technologies is a physics and engineering company with an active fusion group, and a long history in fusion development. The company has been part of the Tokamak de Varennes team since the project began, and is involved in several physics and technology areas during the present commissioning and operations phase. MPBT design work on the Tokamak included eddy current thermal analysis and magnet force analysis for the structure. MPBT also designed and built the control system, much of the data acquisition system, and optical fibre communication systems for control and data signals.

Several diagnostic instruments were supplied by MPBT, including:—

- Laser Thompson scattering receiver.
- 140 GHz interferometer.
- Flux and plasma current measurement loops.

Through MPBT, the TEXTOR project has bought an MPB/INRS-Energie detector system for laser impurity injection measurements (See TEXTOR article and Tokamak Technical Update). MPBT operates and maintains the control systems and the diagnostics it has supplied to Tokamak de Varennes. Ongoing participation in the physics program includes work on radiofrequency plasma heating and on development of kinetic plasma codes.

More information from Dr. M. Bachynski, or Dr. James Castracane (See Contact Data)

CFFTP Highlights

Tritium Dispersion Field Study

A CFFTP/AECL/Ontario Hydro study of environmental oxidation and dispersion of elemental tritium (HT) is nearing completion at Chalk River Nuclear Laboratories (CRNL). Preliminary results indicate that soil microorganisms dominate conversion of HT in the environment to the more toxic oxide (HTO) form.

On June 10 this year, hydrogen gas containing 100 Curies of HT was dispersed over an open field, during a 30 minute period. Air, soil and vegetation samples were taken over a 400 metre distance, starting at the time of the gas release. Participants from Europe, USA and Japan took part in the field studies. The sampling program continues.

Results to date confirm findings of a smaller CRNL/Ontario Hydro dispersion study in 1986, published ir an available 1987 CFFTP report*. Direct conversion of HT to HTO in air, and direct uptake of HT by vegetation are very minor factors in conversion to HTO. Chiefly, environmental HTO resulting from an HT plume dispersion appears to result from HT diffusion into soil and subsequent conversion to HTO by hydrogenase microorganisms. The HTO produced has a long retention time in soil, from where it can be absorbed by plant roots, be resuspended in air, or be re-emitted to atmosphere by evaporation.

Principal Canadian experimenters were R.M. Brown (CRNL), and G.L. Ogram and F.S. Spencer (Ontario Hydro Research Division).

**Report No. CFFTP-G-87004 'Field Studies of HT Oxidation and Dispersion in the Environment, I. The 1986 August experiment at Chalk River. Available via J. Nieswandt, CFFTP.*

CFFTP – TIBER II

During 1986 and 1987, CFFTP staff contributed to the design of the US TIBER II fusion machine. The design was completed in August 1987. TIBER II is a tokamak engineering test reactor of 300MW fusion power with 100% tritium breeding.

Layout: John Blevins worked with staff of the Fusion Engineering Design Centre at Oak Ridge, Tenn., on conceptual design of the TIBER II layout. FEDC has 'A' responsibility for TIBER II facilities layout. The design (including reactor building, maintenance building, and tritium facilities building) aimed at a compact layout, and achieved good success. The reactor hall is a square with 40 m. sides.

Safety and Environment: Robert Stasko worked on assessment of occupational and environmental safety of the machine, and contributed to design changes to improve safety.

Tritium Systems: Paul Gierszewski worked with LLNL on specification of the aqueous lithium salt breeder blanket, tritium recovery systems including water detritiation, and on tritium systems inventory management.

NET Layout and Safety Study

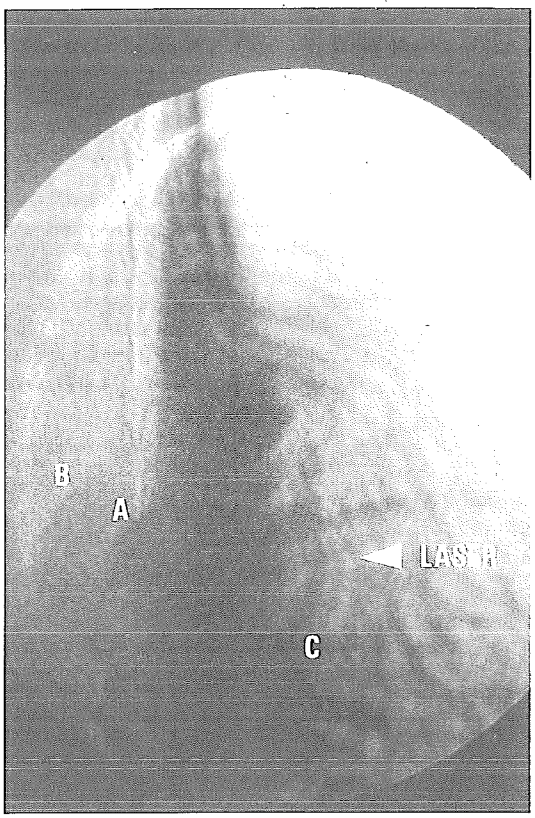
CFFTP has completed this study for the Next European Torus project. Robert Stasko (CFFTP) and George Shaw (Shaw Engineering Services Ltd., Ontario) performed the work for CFFTP between June 1986 and June 1987.

A main requirement of the layout was that all torus components should be replaceable at any time during the machine's life. A design evolved in which the torus is surrounded by a shielding structure to minimize neutron activation of the torus hall crane and structural components.

Safety studies included investigation of the licensability issues of the present NET torus and systems designs in conjunction with the proposed layout.

Further information on above topics from Robert Stasko, CFFTP.

NEXT ISSUE



Shock Waves

Laser-generated high pressure shock wave (A and B) in quartz target shown in double exposure photo of experiment at University of British Columbia (see article next issue). (A) is shock wave at 7 nanoseconds after the 2 nanosecond laser pulse begins impact; (B) is 5 nanoseconds later. Dark region (C) is plasma ablated from quartz target by laser pulse (1.5 Joule, 0.53 microns, 10^{13} watts/cm^2). Maximum shock pressure of about 2 megabar (about 30 million psi) at laser pulse peak has decayed to about 0.3 megabar at (B). Next Issue of 'FusionCanada' describes UBC research.

National Fusion Program

Director, *Dr. David P. Jackson*

The National Fusion Program (NFP) coordinates and supports fusion development in Canada. NFP was established to develop Canadian fusion capability, in industry and in research and development centres. NFP develops international collaboration agreements, and assists Canadian fusion centres to participate in foreign and international projects.

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