AOARD REPORT

A Tour of Japanese Research and Industrial High Power Laser Facilities

July 26-29 1993
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AOARD

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At RIKEN, Dr. Katsumi Midorikawa has been actively pursuing research on high power lasers for more than 10 years. His current research interest is in the development of short wavelength lasers, especially at ultraviolet and soft x-ray wavelength regions. In one of the papers he published in Physical Review Letters, Oct 92, he used a subpicosecond KrF excimer laser to generate higher order harmonic waves via the interaction of the intense laser beam with excited plasmas, such as Li+, Na+, and K+ plasmas.

At the TRDI 2nd Research Center, high power laser research is focused on the development of kilowatt-class CO2 lasers using adaptive optics technology to compensate for atmospheric aberration.

The Mitsubishi Heavy Industries (MHI) R&D Center, located in Takasago, Hyogo Prefecture, uses a 20 kilowatt CO laser (5 micron wavelength) for industrial applications, such as for cutting thick metal sheets. According to MHI personnel, the laser power is sufficient to cut through 30cm thick stainless steel.

Kawasaki Heavy Industries (KHI), located in Kobe, Hyogo Prefecture, has designed and built two 1.0 kilowatt chemical oxygen iodine lasers (COILs) for industrial uses. One is being used at KHI and the second one has been sold to the Applied Laser Engineering Center (ALEC) in Nagaoka, Niigata-ken. Currently, KHI is carrying out research to build a more powerful COIL that can operate in the supersonic region.

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Date: 10 Aug 93

Subject: Trip Report - A Tour of Research and Industrial Laser Facilities, Between 26-29 Jul 93

ABSTRACT:

The following Japanese high power laser facilities were visited between 26-29 Jul 93: the Institute of Physical and Chemical Research (RIKEN) in Wako, TRDI's 2nd Research Center in Tokyo, Mitsubishi Heavy Industries (MHI) in Takasago, Kawasaki Heavy Industries (KHI) in Kobe, and the Applied Laser Engineering Center (ALEC) in Nagaoka.

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Purpose: Accompany the US Air Force's Phillips Lab personnel to Japanese high power laser research and industrial facilities and assess its technology

Place and Time: Laser Facilities at the Institute of Physical and Chemical Research (RIKEN) in Wako, TRDI's 2nd Research Center in Tokyo, Mitsubishi Heavy Industries (MHI) in Takasago, Kawasaki Heavy Industries (KHI) in Kobe, Applied Laser Engineering Center (ALEC) in Nagaoka, between 26-29 July 93 (see Attachment #1 for detailed itinerary)

Observations/comments:

o With the help of Prof Tomoo Fujioka of Tokai University, Lt Col Robert Ligday, Dr Keith Truesdell and Ms Sanae Yata were invited to visit Japanese high power laser facilities at RIKEN, TRDI's 2nd Research Center, MHI, KHI and ALEC. They were invited to Japan by Prof Fujioka for hosting him at Phillips Laboratory in the beginning of this year where he visited the Phillips Laboratory to discuss high power laser research, especially of the chemical oxygen iodine laser (COIL).

o I met Prof Fujioka two weeks prior to Lt Col Robert Ligday's arrival in Tokyo and worked out necessary arrangements for Lt Col Ligday's trip in Japan.

o On Monday, 26 July 93, I met Lt Col Ligday, Dr Truesdell, Ms Yata at the New Sanno Hotel and accompanied them to RIKEN. At RIKEN, we were greeted by Dr Katsumi Midorikawa, who completed a PhD under the supervision of Prof Fujioka at Keio University. Since finishing his PhD in electrical Engineering, Dr Midorikawa has been active in high power laser research at RIKEN for close to 10 years. His current research interest is in the development of short wavelength lasers, especially at ultraviolet and soft x-ray wavelength regions. In one of the papers he published in Physical Review Letters, Oct 92, he used a subpicosecond KrF excimer laser to generate higher order harmonics waves via the interaction of the intense laser beam with excited plasmas, such as Li+, Na+ and K+ plasmas.

o In the most recent paper, presented in QELS'93 conference held in Baltimore, Dr Midorikawa and co-workers reported the experimental verification of amplifying a 13.5 nm x-ray due to the optical-field induced ionization for the first time. Their work was based on a novel idea first described by Burnett and Enright in the IEEE Journal of Quantum Electrons in 1990.

o In the morning of 27 Jul 93, we visited the TRDI 2nd Research Center to see the Japanese Defense Agency's efforts in high power laser research. After the usual introductory remarks by TRDI scientist Dr Saito, Lt Col Ligday presented half an hour overview of the US Air Force's Phillips Laboratory. The presentation was not technical in nature but it served to inform TRDI personnel of the types of research carried out at Phillips Lab.

o In the afternoon of 27 Jul 93, Lt Col Ligday and Dr Truesdell gave presentations to about 20 Japanese scientists and managers. The seminar was arranged by Prof Fujioka of Tokai University at the Arcadia Ichigaya Shigaku-kaikan in Tokyo. Lt Col Ligday gave the overview of the Phillips Lab and then followed by Dr Truesdell who talked on the development of a high power Chemical Oxygen Iodine Laser (COIL) at Phillips Laboratory where the US COIL research started in the middle 70s. Dr Truesdell presented the COIL technology for both subsonic and supersonic designs. As a whole, the seminar was very informative to the audience. It

seems that Japanese companies are starting to get interested on COIL for industrial uses, such as for underwater cutting of a thick metal sheet. I believe the seminar gave good warm feeling to everybody and made aware of the extent of COIL research being carried out in the US.

o Right after completing the seminar we left for Himeji to meet Mitsubishi Heavy Industries personnel the following morning. We left the JR Tokyo station and arrived in Himeji shortly after 2100.

o The Mitsubishi Heavy Industries (MHI) R&D Center is located in Takasago, Hyogo-Ken, only a 10 minute train ride heading east of Himeji on the Sanyo Dentetsu Lines. We met Dr Ayao Tsuge, deputy general manager of the center, and Mr Masaru Ishibashi, manager of the Applied Physics Group. The visit lasted from 920 to 1230 for a bit short of 3 hours. The visit agenda consisted of introduction, laboratory tour, technical discussion, and lunch at their guest house overlooking the Inland Sea. At the beginning there was no tour of the CO laser facility scheduled, so we requested to take out the combustion tour and replace it with the CO laser tour. Our requested was granted and we got to see the CO laser facility. One important observation of this R&D Center is that this place focuses their research in energy related fields, such as nuclear, thermal, and hydraulic energy. Hence, their work is connected very strongly with the Japanese Science & Technology Agency (S&TA). To provide technical service to S&TA, the MHI Takasago R&D Center's basic research effort is divided into five major areas: 1) materials, strength and chemistry; 2) structure, vibration and terramechanics; 3) fluid dynamics and heat transfer; 4) intelligent mechanics and electronics (robotics); and 5) manufacturing. Beside this R&D Center, MHI has five more R&D Centers. They are Advanced Technology Research Center located in Yokohama, Nagasaki R&D Center in Nagasaki, Hiroshima R&D Center in Hiroshima, Yokohama R&D Center in Yokohama, and Nagoya R&D Center. All R&D centers are open for public visits but not the Advanced Technology Center. Only with the special request can one be allowed to visit the Advanced Technology Center.

o MHI has a 20 kilowatt CO laser (5 micron wavelength) used for cutting metal sheets. According to MHI personnel, it has enough power to cut trough a 30 cm thick stainless steel.

o In the afternoon of 28 Jul 93, we visited the Kawasaki Heavy Industries (KHI) in Kobe. We were hosted by Dr Toshio Atsuta, Dr Hiroo Fujii, Dr Kozo Yasuda, and Mr Mikio Mura of the opto-Engineering Laboratory of KHI. We met Dr Fujii at Kobe Kosoku train station at 1330. Then we took taxis for a short distance to KHI, which is located right next to the Inland Sea. In the KHI conference room, KHI personnel explained the status of their subsonic 1 kilowatt COIL and their applications. Dr Keith Truesdell presented pretty much the same talk on subsonic and supersonic COIL technology that he gave in Tokyo to KHI personnel. KHI was really interested on Dr Truesdell's talk since

they are the only company working on COIL in Japan, however in subsonic regime, and would like to build a supersonic COIL for the next phase of their market strategy in high power laser business. The advantage of the supersonic device is that it is possible to increase the laser intensity (or power) by as much as 20 times as proven by Phillips lab researchers.

o We took a tour of the COIL facility. It is very impressive for KHI scientists to build a 1.0 kilowatt COIL in such a short time. It was only two years ago that Dr Fujii went to Russia and US to study the COIL technology. Both Lt Col Ligday and Dr Truesdell were impressed with their development work. Now KHI has sold one COIL, similar to the one we saw here, to the Applied Laser Engineering Center (ALEC) in Nagaoka, Niigata-ken at the cost of 2 million dollars.

o After we had dinner at KHI, we came back to Tokyo that evening. In the following day, 29 Jul 93, we went up to Nagaoka to see laser facilities at ALEC. The center was opened in Apr 92 as part of the Japanese Research Facility Development program, which was sponsored by MITI. The center was built with the intention of providing laser facilities to Japanese and foreign researchers who need to use lasers for the limited amounts of time. There were 11 different types of lasers, ranging from a 5.5 kilowatt CO2 laser to a 1 watt Argon Ion pumped Ring Dye laser, available for use. The COIL laser we saw at ALEC was almost the exact replica of the one we saw at KHI.

Conclusion:

The Japanese high power laser technology has not caught up to the US level yet. The JDA's TRDI 2nd Research Center has been working for a number of years to develop a multi-kilowatt high power CO2 laser and study the atmospheric compensation using a nine actuator adaptive optics system. In the US we have successfully shown the operation of a 241 actuator adaptive optics system, however, for smaller wavelengths (3.8 and 1.06 microns).

The Japanese companies, such as MHI and KHI, are investing money to design high power lasers for industrial applications. MHI's 20 kilowatt CO laser and KHI's 1.0 kilowatt COIL are good examples. Based on visits I made to these company, I see that these companies are actively pursuing basic research to increase the laser power to higher levels.