Equipment Development Center

VIII-K Development of “IMS Machines”

The technical staff of the Equipment Development Center is partly engaged in planning, researching, designing and constructing “IMS machines.” This machine, crowned with the acronym of the Institute for Molecular Science, is a high-tech experimental instrument, with emphasis on new technical idea and co-operative work with members inside and outside the Institute including those in industries. We collect suggestions of new instruments once every year from all of the members of IMS.

In this fiscal year, 1999, three project themes (1 thorough 3) were adopted as IMS machines. IMS machine projects 4 (IMS machine 1998) was completed, and project 5 (IMS machine 1998) is under way.

1. **Sorption-pump-type Large-scale Dilution Refrigerator**
   (proposed by Hideo SHIBAYAMA and Takuhiko KONDOH)
2. **Vacuum-chamber-based High Voltage Application Apparatus to Fabricate Wide-range Nonlinear Optical Wavelength Converters**
   (proposed by Sunao KURIMURA, Takunori TAIRA, Kazuhiro KOBAYASHI and Mitukazu SUZUI)
3. **High-speed Array Detector**
   (proposed by Kazuo WATANABE and Hisashi YOSHIDA)
4. **Thin Shaped Cryostat for Opt-magnetic Measurement**
   (proposed by Shinji IZUMIDA and Takuhiko KONDOH)
5. **Preparation and Transfer System for Ice-embedding Sample**
   (proposed by Shinji HASEGAWA, Kazuhiro KOBAYASHI and Mitukazu SUZUI)

VIII-K-1 Vacuum-Chamber-Based High Voltage Application Apparatus to Fabricate Wide-Range Nonlinear Optical Wavelength Converters

KURIMURA, Sunao; TAIRA, Takunori; KOBAYASHI, Kazuhiro; SUZUI, Mitsukazu

This project aims at development of a vacuum-chamber-based high voltage application apparatus, which allows precise fabrication of a ferroelectric domain pattern in nonlinear optical materials. The reversal of ferroelectric spontaneous polarization is accompanied by the change of the sign of nonlinear optical coefficient, which enables quasi-phase matching (QPM) in wavelength conversion of laser light. QPM, where the period of the domain pattern corresponds to the generated wavelength in optical parametric oscillator, is an universal method to realize phase matching artificially at arbitrary wavelength (Figure 1). Periodic electrodes defined by photolithography are transferred to the domain pattern if the fidelity, affected by the atmosphere such as insulator, electrode materials, and temperature of a crystal, is reasonable (Figure 2). A widely-spread conventional technique using liquid electrodes is simple and easy, but it greatly increases the conductivity between electrodes, leading to the poor fidelity with expanded domains. While our experimental results on poling indicated the atmosphere of insulating oil and photoresist were not appropriate for high fidelity, vacuum atmosphere is an ultimate candidate to suppress surface conductivity. Temperature of the material, another important parameter, affects the domain-nucleation density and the domain wall velocity; temperature control is essential in the system. *Vacuum-based poling apparatus covering wide temperature range*, is a challenging and promising project in fabrication of QPM devices.

We so far designed the apparatus and mainly built the vacuum-related section. Requirements for this system are summarized in Table 1. The poling system consists of three parts: a vacuum chamber, a high voltage supplier, and a temperature controlling unit. The vacuum chamber with 35 cm diameter and 32 cm height was built and high-speed vacuum pumps, a rotary pump and a diffusion pump were equipped into the system. The custom-made flanges were installed to fit the pumps with high exhaust velocity to the chamber. The carefully-checked vacuum system achieved 1×10^{-7} Torr and met our vacuum requirement in such a large chamber. It is now in the final stage of other mechanical parts assembly and will be completed at the end of this August. Another checking point was the ability of high voltage application. Since the required voltage for poling is 22000 V, which is not a low hurdle, we carefully chose shielding electric parts to meet our specification. Specially-designed flanges were provided for electric connection to fit the system. The final difficulty that we are now facing with, is in a crystal mount in a copper setting with heater and cooling pipes to stabilize the temperature. We are planning to place designed cooling pipes to obtain temperature uniformity and a sheathe-shaped heater to meet the short response time as shown in Figure 4. We expect that the assembly will be finished at the end of August and total system will get ready as early as the end of September. We appreciate kind cooperation and meaningful suggestions from all related persons.

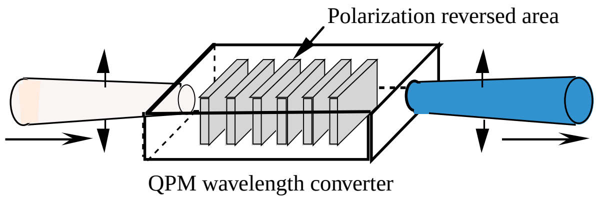

Figure 1. QPM wavelength converter to be fabricated by the vacuum-chamber-based high voltage application apparatus.

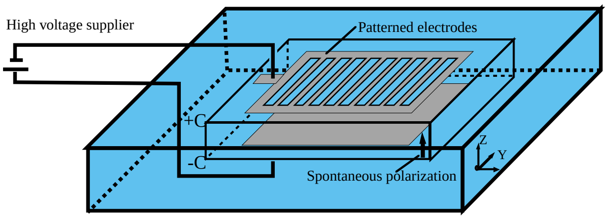

Figure 2. Fabrication method of a periodically poled QPM device.

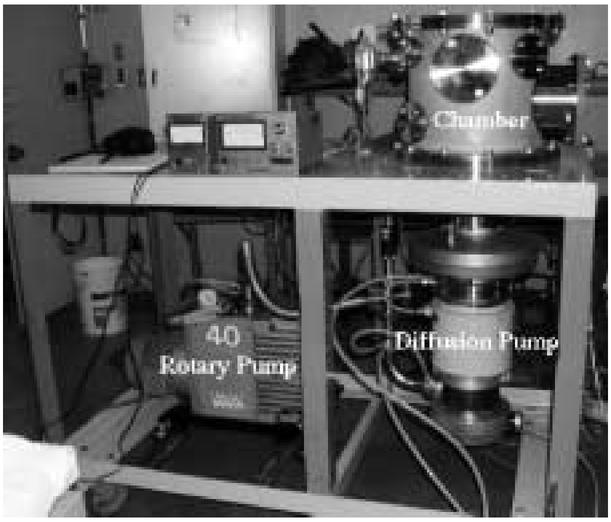

Figure 3. Overall picture of the vacuum system.

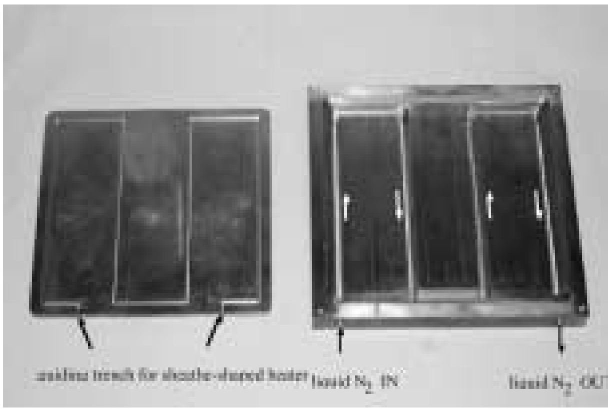

Figure 4. Crystal mount with the cooling pipes and the sheathe-shaped heater. The geometry is designed to have uniform temperature distribution and short response time.

Table 1. Requirements for the apparatus.

Voltage (V)	Vacuum (Torr)	Temperature (°C)	Crystal size
24000	$10^{-3} \sim 10^{-7}$	–180 ~ 150	3 inch Φ

VIII-L Development of New Laser Materials

VIII-L-1 Deep-Ultraviolet Uight Amplification within a Nanometer-Sized Layer

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Light amplification in the deep-ultraviolet region within a nanometer-sized layer is confirmed in mixed rubidium-cesium chloride crystals at room temperature. The probe laser light, which falls on the 275-nm band of Auger-free luminescence arising from radiative transition of the Cl 3p valence electrons into the Cs 5p core holes, is enhanced in intensity when the deep-lying Rb 4p core electrons are pumped into the conduction band by undulator radiation from UVSOR electron storage ring. The obtained enhancement factor roughly corresponds to an amplification coefficient of 7×10^3 /cm, which is much higher than those of typical solid-state lasers. It is emphasized that the amplification occurs in a surface layer as thin as about 20 nm, and that the inverted population between the valence and core bands is realized with any pump power. The present observation may open a new way for nanolaser fabrication.