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FOREIGN TRIP REPORT

ORNL/FTR-3416

DATE: October 13, 1989

SUBJECT: Report of Foreign Travel of Y. Chen, Senior Research Staff Member, Ceramics and Interfaces Section, Solid State Division

TO: Alvin W. Trivelpiece

FROM: Y. Chen

Purpose: To present an invited talk at the Fifth International Conference on Tunable Lasers, Irkutsk, Siberia, USSR; to visit the Irkutsk State University, Irkutsk, Siberia, USSR; to visit the General Physics Institute, the Academy of Sciences of USSR, Moscow, USSR, as an official guest of the Belorussian Academy of Sciences (Minsk); and to visit the Institute of Radioengineering and Electronics of the Academy of Sciences of the USSR, Moscow, USSR.

Sites Visited:			
	9/20–23/89	Tunable Laser Conference, Irkutsk, Siberia, USSR	V. V. Osiko
	9/24/89	Institute of Applied Physics, Irkutsk State University, Irkutsk, Siberia, USSR	E. F. Martynovich
	9/25–27/89	General Physics Institute, Academy of Sciences of the USSR, Moscow, USSR	T. T. Basiev
	9/28/89	Institute of Radioengineering and Electronics, Academy of Sciences of the USSR, Moscow, USSR	V. F. Zolin

Abstract: The traveler presented an invited talk entitled "Prospect for Wavelength Tunable Lasers Based on Vacancy Defects in Alkaline-Earth Oxides" at the Fifth International Conference on Tunable Lasers in Irkutsk, Siberia, USSR. In addition, he also visited the Irkutsk State University in Irkutsk, Siberia, USSR; the General Physics Institute, the Academy of Sciences of the USSR, Moscow, USSR; and the Institute of Radioengineering and Electronics, the Academy of Sciences of the USSR, Moscow, USSR.

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I. FIFTH INTERNATIONAL CONFERENCE ON TUNABLE LASERS, IRKUTSK, SIBERIA, USSR

The Fifth International Conference on Tunable Lasers was of moderate size—281 participants from 20 countries. There were 44 oral presentations, including both invited and contributed talks, and 130 posters; the latter were exclusively from the USSR. Seven scientists from the United States participated in the conference.

The scientific program covered most of the basic current research directions related to solid state tunable lasers. The subjects included energy transfer, multiphonon processes, spectroscopy of rare-earth and transition-metal impurities in different hosts, defect production, shapes of devices, and instrumentation and industrial applications; the latter pertain primarily to the medical fields. The central emphasis of the conference was on the physics of impurity-doped and color-center lasers. The topics discussed included not only the more conventional hosts, such as YAG and sapphire, but also new garnet materials. The languages of the conference were Russian and English, and simultaneous translation was provided.

The keynote speaker was F. Luty of the University of Utah, and the title of his talk was "Energy Transfer, Raman Scattering, IR Vibrational Fluorescence and Multiline 5-μm Laser Operation of F Center/CN^- Pairs." Electronic excitation of F centers (anion vacancies) produces energy transfer into higher CN vibrational states. Experiments on nine alkali halide hosts were reported. The potential for multiline laser operation of these systems can apparently be realized in the future.

The traveler's talk was entitled "Prospects for Wavelength Tunable Lasers Based on Vacancy Defects in Alkaline-earth Oxides" in which he (1) outlined the advantages and problems involved in using vacancy defects for tunable lasers in the alkaline-earth oxides, (2) discussed the advantages of using vacancies produced by thermochemical reduction (a process developed at ORNL) over those produced by neutrons, and (3) provided experimental results which show that neither the F^+ nor F centers (the two-charge states of the anion vacancies) in CaO and MgO can serve as a laser-active color center unless the electronic wave functions at the defects can be made more compact—perhaps by the presence of an adjacent impurity. After the

traveler's talk, he was immediately contacted by several Russian scientists, along with a translator, who noted that cw tunable lasing action has been reported for the F^+ center in CaO by a scientist from the University of Dublin, and they asked for the traveler's comments. This system is of special interest in the scientific world because it is the only reported solid state tunable laser operating in the ultraviolet region, and lasing in the short-wavelength region is extremely difficult because the optical gain is proportional to the square of the wavelength. In response, the traveler went into further scientific detail on why it should not lase and indicated that the reported work at Dublin was not reproducible in Germany or the United States. The traveler felt that they were already aware by word of mouth that this system was not reproducible.

One of the most interesting events during this trip was a meeting with S. M. Gladkov, who is the Deputy Director for Scientific Programs, Scientific and Engineering Center of "Progress," a high-technology "public" company not owned by the state. This company is a year old and came into existence as a result of perestroika. The company employs university professors on a part-time basis and pays them salaries that are two or three times higher than their university pay. The professors report directly to the company, and there are currently about 1,000 Ph.D.s on the payroll. The operating budget for the past year was 5 million rubles. Because of its mission-oriented programs, one of the strong assets of this company is the multidisciplinary research among scientists. Traditionally, funding from the government is very conservative and discourages interaction even among researchers in different departments of the same university. Gladkov made no pretense that he was soliciting work for his company, especially from foreign countries. His argument is that work can be done more economically in the Soviet Union. Highly trained full professors earn something like 500 rubles per month.

II. VISIT TO THE STATE UNIVERSITY OF IRKUTSK, IRKUTSK, SIBERIA

The traveler visited on a Sunday, and the State University of Irkutsk was closed. E. F. Martynovich, who is well-known for his work on sapphire, picked the traveler up for a short visit to his laboratory before the bus pickup

to the airport. The traveler spent 30 minutes with Martynovich in his laboratory discussing mutual work on sapphire. He indicated that he would like to have the traveler spend a month in his laboratory and that he would write a letter of invitation shortly.

His laboratory was rather small and crammed with equipment that was stacked six-tiers high. Although the traveler did not visit other professors' laboratories, he could imagine what they were like, given that Martynovich is probably the most well-known physicist at that university. Martynovich indicated that he is now working on LiF and hopes to investigate TiO_2 but could not find TiO_2 anywhere in the USSR. The traveler told him that he worked briefly on TiO_2 and that he might still have a small piece that Martynovich could have. Martynovich was elated at this prospect.

III. VISIT TO THE GENERAL PHYSICS INSTITUTE, ACADEMY OF SCIENCES OF THE USSR, MOSCOW, USSR

The traveler's hosts at the institute were T. T. Basiev and S. B. Mirov of the Solid State Department. The various sections of the department include the following:

(1) Laser Spectroscopy of Solids, headed by T. T. Basiev
(2) Materials for Electronic Techniques and Optics, headed by M. I. Timoshechkin
(3) Highly Concentrated Laser Materials, headed by B. I. Denker
(4) Spectroscopy of Glasses and Crystals, headed by Yu. K. Voronko
(5) Crystal Growth, headed by V. M. Tatarintsev
(6) Skull Melting, headed by V. I. Alexsandrov

The traveler's first visit to the institute was with E. V. Zharikov, whom the traveler had invited to be a co-chairman of a symposium at the 1983 Materials Research Society held in Boston. Zharikov was unable to attend that meeting, because of the Korean Airline 007 incident. Zharikov, an innovative crystal grower, grows crystals primarily for medical and biological applications. The crystal hosts are mostly garnets. The dopants are typically holmium, erbium, and the double dopants of Cr and Nd to produce lasers that operate in the infrared and far-infrared regions. Holmium lasers operate in the 3-μm region, Er at 1.5 μm, and Nd at 1.06 μm. One of Zharikov's

innovations involves introducing a low-frequency vibration to the seed during Czochralski crystal growth. This procedure allows control of the convective movement of the melt and the shape of the interface during the crystal growth.

Denker produces large phosphate glasses, some of which weigh close to 7 kilograms doped with high concentrations of rare-earth impurities. The emphasis is on three types of dopants: the first is triply doped, intended for energy transfer from Cr to Yb to Er; the second is also triply doped, with energy transfer from Nd to Yb to Er; and the third is doubly doped, with energy transfer intended from Yb to Er. Denker also grows fosterite and garnet crystals.

Mirov specializes in color center lasers, using primarily LiF crystals. He has been able to obtain lasing for three defects in LiF crystals: the F_2 center, which peaks at 700 nm; the F_2^+ center, which peaks at 920 nm; and the F_2^- center, which peaks at 1140 nm. The traveler expressed surprise that the F_2^- center lased at all, since the wave function of the excited electron is too diffuse. Mirov admitted that they introduced an adjacent divalent cation impurity to compact the electronic wave function at the vacancy. He would not be drawn into a discussion on the size of the divalent impurity ion necessary to stabilize the electronic wave function, obviously for proprietary reasons. At one point, Mirov pointed out, with veiled disdain, that Burleigh Instruments in New York is quite successful in marketing a tunable laser that has to be operated at cryogenic temperature. He told the traveler that his LiF laser is simple to use and operates at room temperature. He then proceeded to prove his point. Finally, he remarked that he is already thinking about the next generation of color-center tunable lasers, of miniature size, to be used in miniature optical devices. Mirov has already used intense soft X rays to produce high concentrations of vacancies in a 3-micron thick layer.

IV. VISIT TO THE INSTITUTE OF RADIOENGINEERING AND ELECTRONICS, ACADEMY OF SCIENCES, MOSCOW, USSR

The traveler visited V. F. Zolin and S. G. Lukishova at this institute. The former claims to have produced lasing action of Nd in powders of $Na_5La(MoO_4)_4$. This work was published in the *Journal of the Soviet*

Quantum Electronics in 1986. This is the first time the traveler has heard that lasing action has been produced in powders. It seems that scattering from the particles would destroy the coherency of the light beam. No one at the General Physics Institute had mentioned Zolin's work, even though he is an academician and apparently enjoys the respect of his peers. The traveler has not yet read Zolin's paper on this subject. Zolin also performs research on organic compounds and has done work on proton-deuteron exchange using infrared techniques. He was not aware that ORNL does similar experiments on inorganic compounds, including proton-tritium exchange, with the tritium derived from nuclear transmutation of ^{6}Li.

V. GENERAL OBSERVATIONS AND COMMENTS

The research facilities of the General Physics Institute of the Academy of Sciences of the USSR are generally regarded as the best in the USSR. The traveler's observation acknowledges that distinction. All the laboratories that the traveler visited appeared to be crammed with equipment.

The scientists whom the traveler met appeared to be very innovative. Laser research has always been heavily emphasized in the USSR, and their crystal-growing efforts are outstanding. Several of the pioneering research programs on laser hosts originated in Zharikov's crystal-growing laboratory.

Finally, the traveler found the Russians to be very friendly. No doubt perestroika has something to do with their attitudes. Perestroika also means "tunable." Therefore, this word was used frequently at the conference. The Russian scientists were quite open about what they do, and the normal scientific exchange was generally uninhibited. The traveler appreciates the hospitality of his Russian hosts.

APPENDICES

A. ITINERARY

B. LITERATURE ACQUIRED DURING FOREIGN TRAVEL

APPENDIX A

ITINERARY

DATES	LOCATION	INDIVIDUALS CONTACTED	SUBJECT OF DISCUSSION
9/18–19/89	Travel from Oak Ridge, TN, to Irkutsk, USSR, via plane		
9/20–23/89	Irkutsk, USSR	V. V. Osiko S. M. Gladkov	Fifth International Conference on Tunable Lasers
9/24/89	Institute of Applied Physics, Irkutsk State University, Irkutsk, Siberia, USSR	E. F. Martynovich	Discussions on tunable lasers in sapphire
9/25–27/89	General Physics Institute, Academy of Sciences of USSR, Moscow, USSR	T. T. Basiev B. I. Denker S. B. Mirov E. V. Zharikov	Discussions on tunable lasers in oxides and fluorides
9/28/89	Institute of Radioengineering and Electronics, Academy of Sciences of the USSR, Moscow, USSR	V. F. Zolin S. G. Lukishova	Discussions on tunable lasers in powder
9/29–30/89	Travel from Moscow, USSR, to Oak Ridge, TN, via plane		

APPENDIX B

LITERATURE ACQUIRED DURING FOREIGN TRAVEL

1. *Reprint,* T. T. Basiev, S. B. Mirov, and V. V. Osiko, "Room-Temperature Color Center Lasers," *IEEE J. Quantum Electron.* **24**, 1052 (1986).

2. *Preprint,* S. P. Kalitin, M. A. Noginov, V. G. Ostoumov, V. A. Smirnov, A. F. Umyskov, and I. A. Shcherbakov, "Nonlinear Interactions of the Excited Ions in the Laser Crystal YSGG:Cr^{3+}:Er^{3+}," *Proceeding of Optika 1988* (in press).

3. *Preprint,* M. A. Noginov, V. A. Smirnov, A. F. Umyskov, and I. A. Shcherbakov, "The Excited Ions Interaction of Er-Ions in the Crystal of Yttrium Scandium Gallium Garnets," *unpublished* (in Russian).

4. *Preprint,* V. F. Vlasov et al., "Growth Automization Research Complex," *unpublished* (in Russian).

5. *Preprint,* F. V. Volosina et al., "Precision X-Ray Analyses of GSGG," to appear in *Doklady* (in Russian).

6. *Preprint,* E. V. Zharikov et al., "Investigations of Temperature Distribution in the Melt During Crystal Growth by Czochralski Method," *unpublished* (in Russian).