Stanford Picosecond FEL Center
Final Report for Contract # N00014-91-C-0170

Through Contract # N00014-91-C-0170 the Office of Naval Research provided a total of $ 8,483,050 in support of the Stanford Picosecond FEL Center. Although the award period for the contract was 1 September, 1990 through 31 December, 1993, funds did not arrive at Stanford until 21 August, 1991, one full year after the start date. A one year no-cost extension to 31 December, 1994 was granted to permit completion of the proposed work. Concurrent support for the Center was provided by the Office of Naval Research during the nine month period 1 April, 1994 through 31 December, 1994 (Grant #N00014-94-1-1024).

FEL Operations

In the subject contract Stanford was obligated to provide a total of 3000 hours of FEL experimental time (a rate of 1000 hours per year). As of 31 December, 1993 a total of 2161 hours of experimental time had been delivered and as of 31 December, 1994, the end date of the contract, a total of 4218 hours had been delivered. A twelve-month moving average of FEL experimental time, as proposed and as delivered, is shown in Fig. 1. The shaded portion of the curve indicates concurrent (or parasitic) experimental time. The percentage of FEL experimental time allocated to Core User Groups, External User Groups and to System Development during each running period is shown in Fig. 2. The influence of the 16th

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IN REPLY REFER TO:

4330
ONR 247
11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105

To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

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15 August 1995

Defense Technical Information Center
Bldg. 5, Cameron Station
Alexandria, VA 22314

Subject: Final Report

Reference: Contract N00014-91-C-0170, Stanford Picosecond FEL Center

Dear Madam/Sir;

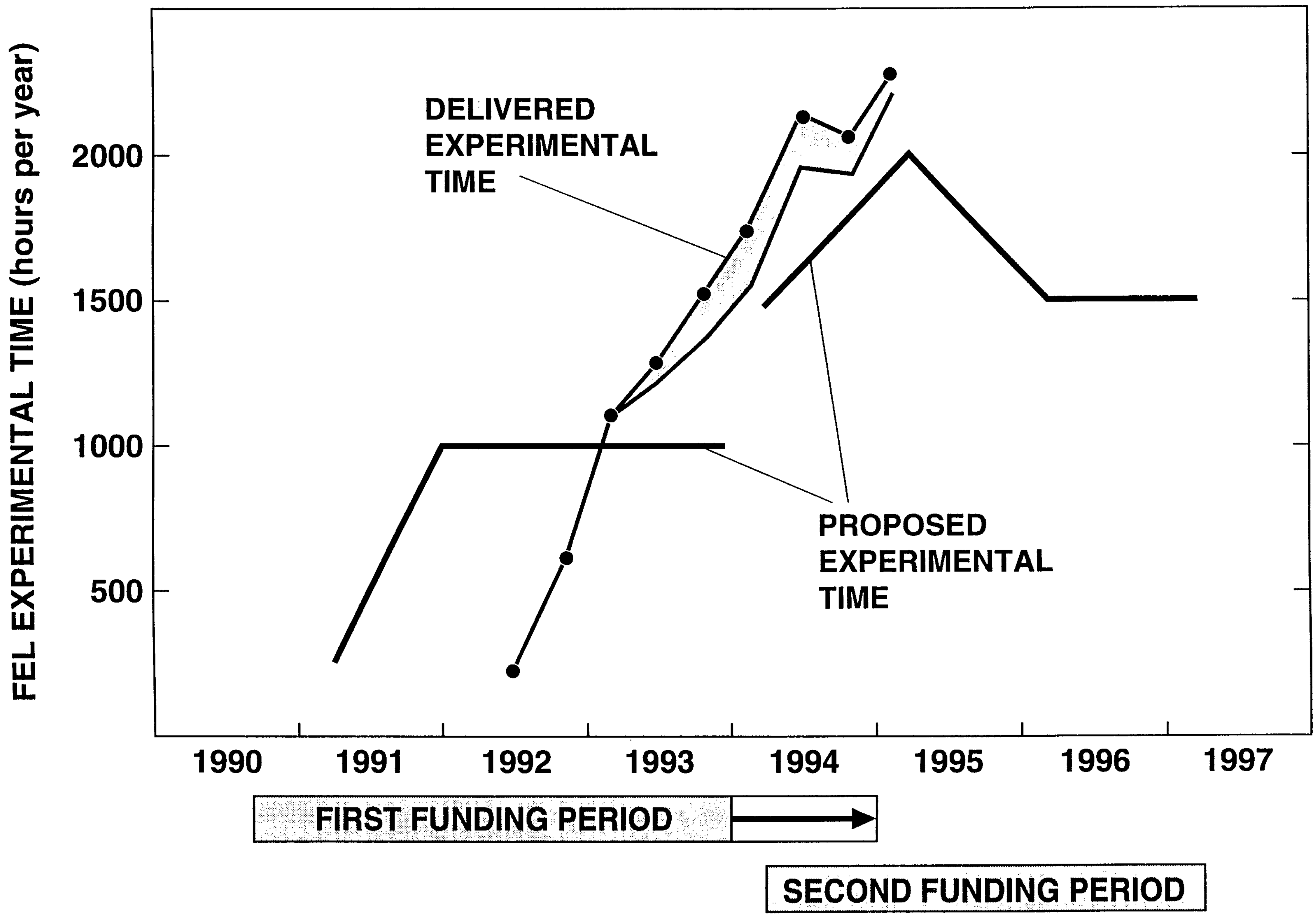
Four copies of a Final Report for the referenced Contract are submitted for your records as required by the Contract Data Requirements List, Enclosure Number 1. Should you have any questions concerning this submittal please contact me at (415) 723-0102.

Sincerely;

Robert A. Farnsworth
Associate Director

19950824 066

FEL EXPERIMENTAL TIME: 12 MONTH MOVING AVERAGE



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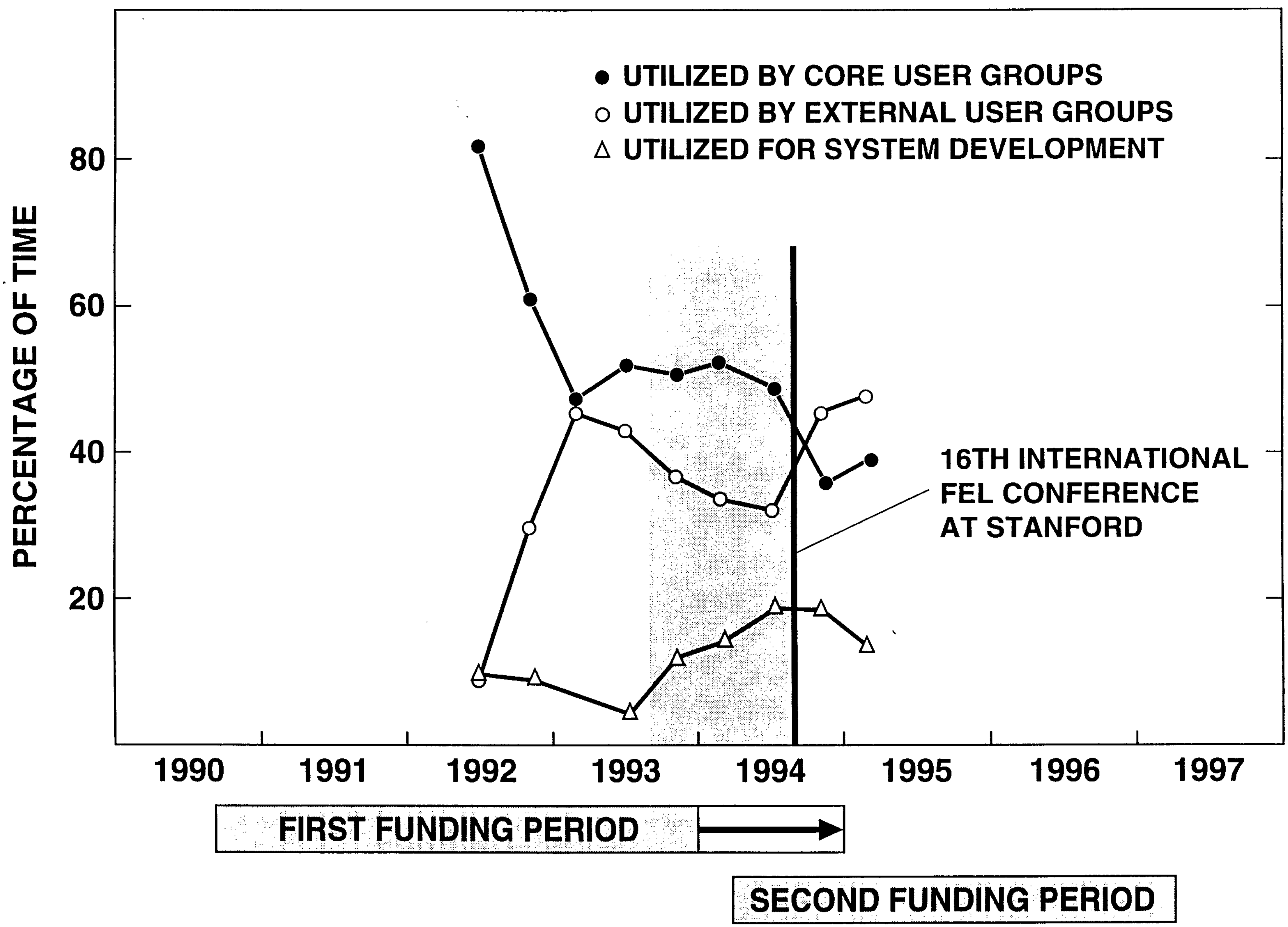
FEL EXPERIMENTAL TIME



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International FEL Conference, held at Stanford in August, 1994 is evident. In the twelve months preceding the conference, FEL beam time was allocated to those experiments most likely to yield publishable results. Furthermore, a special effort was made to complete our optical diagnostics and control systems and the far-infrared FEL known as "FIREFLY". These factors temporarily created a bias away from External User Group research. Despite this, 36.4% (1534 hours) of the total experimental time through 31 December, 1994 was allocated to External Users. During this same time period 50.8% (2134 hours) was allocated to Core User Groups and 12.8% (541 hours) to System Development.

FEL Center Publications

During the period of this contract the Stanford Picosecond FEL Center clearly passed the threshold of scientific productivity. In the four year period, 1991 through 1994, a total of 110 scientific papers describing work at the Center were written; 59 of these were published or accepted for publication in refereed scientific journals. More than half of these papers were produced in CY 1994 alone. In the last year there were 67 papers written of which 34 were published or accepted for publication in refereed journals. In addition four students earned Ph.Ds. in 1994 based on their research at the Center. A complete list of Stanford FEL Center Publications through 31 December, 1994 is appended to this report.

Not all of the Center publications describe experiments performed with the FEL. Some of the publications were theoretical in nature and others were based on use of the FTIR and the conventional lasers available at the Center. In the four year period of this contract there were 45 publications describing FEL experiments and 27 of these appeared in refereed scientific journals. Again, more than half of these appeared in CY 1994. Based on our experience, more than 100 hours of FEL experimental time is required for each refereed publication.

FEL Conference and Users Workshop

The Sixteenth International Free Electron Laser Conference was held August 21-26, 1994 at Stanford University. The Conference was organized by the Stanford Picosecond FEL Center and was attended by 230 registered participants from 15 different countries. Scientific contributions to the conference included 48 invited oral presentations and 179 poster presentations. The contributions attest to the vigor and the diversity of interests within the field.

Following the conference, the Stanford Picosecond FEL Center hosted the first International FEL Users Workshop. There were 116 registered participants and 75 scientific contributions. The success of this first Users Workshop has resulted in plans for a second workshop in New York in 1995, and a third workshop in Rome in 1996.

Core Research Group Activities

Core research groups were established at the Stanford Center in FEL Science under the direction of Professor T. I. Smith, in Chemistry under the direction of Professor M. D. Fayer, in Biology under the direction of Professor P. C. Hanawalt and in Medical Science under the direction of Professor E. A. Bauer. The core groups were established with the expectation that each group would launch its own program of research at the Center, serve as a nucleus of support for External Users, and participate in the development of new experimental capabilities. Some of the core groups fulfilled this expectation better than others with the consequence that the groups in Biology and in Medical Science were disbanded and new core groups in Solid State Science under the direction of Professor H. A. Schwettman and in Biophysics under the direction of Professor S. G. Boxer were established. At the end date of the contract we were near the point of establishing a new medical science core group.

Although the Stanford FEL Center is committed to supporting optical science that makes direct use of the conventional lasers and other optical instrumentation available at the Center, the central mission of the Center is to exploit the special capabilities of the FEL. In Table I we have indicated the FEL Experimental Time utilized by each core group. Since an important function of the core group is to provide support for external users, we have also indicated FEL User Time Supported by each group. The record of FEL related publications for each group, including support activities, is also

Table I: FEL ACTIVITIES OF CORE GROUPS

Core Group	FEL Expt'l Time Utilized	FEL User Time Supported	FEL Publications Refereed	FEL Publications Other
Smith	735 (116)†	181(159)†	12	3
Fayer	916	166	9	5
Hanawalt	0	0	0	0
Bauer	0	0	0	0
Schwettman	287	1028	6	10
Boxer	89	0	0	0

† Concurrent time is indicated in parentheses.

presented in the table. It should be noted that User support activities often involve work outside the indicated discipline of the core group. For instance, most of the User Support activities of the Fayer group have involved Biophysics.

Collaborator/User FEL Activities

As mentioned earlier, 36.4% of the FEL Experimental Time was provided to collaborator/user groups during the contract period. Nine separate groups made significant use of experimental time (more than 50 hours) and the number of groups is growing. A detailed accounting of collaborator/user groups (and specific experiments), allocated FEL experimental time, FEL publications (both refereed and other) and funding provided by the Center through the Applications Research Program is given in Table II. Since success in these activities is strongly dependent on support provided by the core groups, the support group for each collaborator/user experiment is also indicated. Under FEL Publications we have indicated papers in preparation (IP) and start-up experiments (SU).

Collaborator/User Non-FEL Activities

<u>Applications Research Projects</u>: Proposals submitted by Professor Colson of the Naval Postgraduate School and Professors Boxer, Chu and Hanawalt of Stanford were funded through the Applications Research Program, although none of these utilized FEL experimental

TABLE II: COLLABORATOR/USER FEL ACTIVITIES

Investigator	Institution	Investigation	Support Group	Center Funding	Expt'l Time	FEL Publications Refereed	FEL Publications Other
Leemans	LBL	Microp.Diagn	Smith	--	28(159)	2	2
Richman	-	FROG Diagn	Smith	--	25	0	IP
Wiedemann	Stanford	Bunch Monitor	Smith	25K$	57	1	0
Fauchet	Rochester	Carrier Dynam.	Schwettman	--	--	1	2
Fauchet	Rochester	QW (SHG)	Schwettman	127K$	233	2	4
Fauchet	Rochester	QW (P-p)	Schwettman		51	1	0
Fauchet	Rochester	Amorph Si	Schwettman		12	SU	SU
Fejer/Harris	Stanford	QW (SHG)	Schwettman	50K$	277	2	2
Fejer/Harris	Stanford	QW (P-p)	Schwettman		45	IP	IP
Dlott	Illinois	Energetic Mat'ls	Fayer	see below	4	0	1
Kelley	Dupont	Surface Mod	Smith	--	36	SU	SU
Simon	UCSD	Reactive Interm	Fayer	30K$	8	0	0
Warren	Princeton	Ladder Climbing	Fayer	46K$	16	0	0
Austin	Princeton	Acetanilide P-p	Schwettman	--	8	SU	SU
Dlott	Illinois	Myoglobin P-p	Fayer	187K$	138	1	1
Erramilli	Princeton	Near Field Micros	Smith	--	19	SU	SU
Henderson	Fisk	Hole Burning	Schwettman	--	53	0	1
Mathies	UCB	Bacteriorhodopsin	Schwettman	38K$	55	0	0
Peterson	N.Mex.State	Protein P-p	Schwettman	--	67	IP	IP
Benaron	Stanford	Absorp/Scatt.	Schwettman	--	15	SU	SU
Edwards	Vanderbilt	Ablation	Smith	--	16	0	0
Hill	UCI	Ablation	Schwettman	--	10	SU	SU
Oraevsky	Rice	Photoacoustics	Schwettman	15K$	18	0	0
Tromberg	UCI	P-p Micros.	Schwettman	--	184	0	1
					1375(159)	10	14

time. Professor Colson's work involved calculations important to the operation of our FEL and Professor Boxer's work has gradually evolved into FEL experimentation. Professor Boxer now heads a Core Research Group in Biophysics. Although the work of Professors Chu and Hanawalt represents important science, support for their research was discontinued when it became clear that involvement at the FEL Center was minimal.

BLIMC/Stanford Collaboration: The BLIMC/Stanford collaboration, funded jointly by the present contract and by an endowment grant from the Beckman Foundation to BLIMC, was established to provide seed money for pre-clinical and clinical research projects. Six projects, proposed by Professors Danasouri, Karasek, Lane, Maurice, Reese, and Wittich, all of the Stanford University Medical Center, were funded through this program. Professor M. Berns, Director of the Beckman Laser Institute at U.C. Irvine, took an active role in encouraging the proposals and in carrying out the projects while he was at Stanford on sabbatical leave during Academic Year 1991-92.

Medical Research Projects: Funds for medical research projects were provided by the Stanford FEL Center to Professor S. Smith, S. Kim, D. Benaron, E. Bauer, and J. Spudich, all of the Stanford University Medical Center, with the expectation that an increased medical research activitiy at the FEL Center would result. The groups of S. Smith and D. Benaron, indeed, have become involved and we hope to establish a new Medical Science Core Group soon.

Center Equipment and Facilities

Optical Facilities: A single beam optical facility was established during the period of this contract and utilized in measurements of the second order nonlinear susceptibility of both conduction band and valence band quantum well structures, in measurements of two photon absorption in narrow gap semiconductors and in preliminary ablation studies. The work on quantum well structures led to the first demonstration of difference frequency generation of mid-IR light in any quantum well system. This, in turn, opens the possibility for monolithic diode laser pumps and compact waveguide frequency converters as tunable mid-IR sources.

In addition, a multiple beam optical facility was established at the Center for pump-probe and photon echo measurements. The multiple beam capability has been utilized in measurements of carrier relaxation in quantum well structures and in measurements of vibrational dynamics in glass-forming liquids and in proteins. The experiments on glass-forming liquids represent the first vibrational photon echo measurements and the first comprehensive temperature dependent vibrational pump-probe measurements on any system. The combined measurements allow decomposition of the total homogenous vibrational linewidth into individual components: pure dephasing, orientational diffusion, and population lifetime.

A variety of two-color optical capabilities are also being developed, including a two-color pump-probe, an IR pump-Raman probe, and a pump-probe microscope capability. Although the two-color capabilities are not as fully developed, we expect some of these to produce publication quality data in the near future.

Optical Transport, Diagnostics and Control: An optical transport system that distributes the FEL beam to any one of six separate experimental areas has been installed. In addition, to assure reliable beam delivery and to maximize productivity of Users, we developed a sophisticated system of optical diagnostics and control. An integrated display has been made available in all experimental areas which provides continuously updated measurements of beam spectrum, micropulse duration, power, position and pointing -- all of which may be saved to document beam conditions during an experiment. The optical beam is actively wavelength stabilized to better than 0.01 percent and direct wavelength control is available to Users in every experimental area. With direct User control, wavelength changes as large as a few percent are possible while larger shifts are readily available with operator assistance.

FEL Undulator Systems: During this contract period a new mid-IR FEL system, replacing the TRW FEL system, was brought into operation. With this new system the FEL power has been increased by approximately a factor of two and the accessible wavelength has been extended beyond 10 microns. Better mechanical installation has also improved the stability and reliability of FEL operation.

The replacement of the mid-IR FEL system was carefully planned and executed to minimize impact on the experimental program. The sequence of activities and the scheduling with respect to FEL operations is shown in Fig. 3. The shaded bands indicate FEL operating periods. Design of the mid-IR FEL system was completed and fabrication begun in 1992. Installation proceeded immediately after the Jan/Feb 93 operating period. In this first installation phase, the undulator, the electron beamline and the e-beam diagnostics were installed. These were tested with electron beam during the June/July 93 operating period. Following this, in a second installation phase, the FEL optical cavity systems were installed. Our objective during the Sept/Oct 93 operating period was to achieve first lasing and initial characterization of this new FEL system. We were concerned that first lasing tests proceed smoothly and to this end developed a novel method of measuring optical cavity length using an external laser. During the Sept/Oct 93 operating period first lasing and initial characterization was accomplished using just 48 hours of beam time. Finally, prior to the Feb/Mar 94 operating period, the new mid-IR FEL was connected and matched to the existing optical beam transport system. Although the optics were not ideal in the sense of being able to transport the longest wavelength beam, we felt it was imperative that we be able to switch back to the TRW FEL system in less than one day if the experimental program were adversely affected. In fact, the experimental program proceeded smoothly and the new mid-IR FEL was used exclusively during 1994, the most productive year at our Center.

As shown in Fig. 3, installation of a new far-IR undulator known as "FIREFLY" proceeded in a similar fashion. Design of this system was completed and fabrication begun early in 1993. The first installation phase followed immediately after the June/July 93 operating period. Although first lasing with "FIREFLY" proved to be more difficult than with the mid-IR system, installation and testing proceeded without adversely affecting the experimental program. First lasing was achieved during the Oct/Nov 94 operating period.

Conventional lasers and other optical instrumentation: The Center has invested in three commercial high power short pulse laser systems: a nanosecond Nd:YAG laser, a picosecond dye laser pumped by a Nd:YLF and a femtosecond Ti:Sapphire laser. These lasers have all been synchronized to the FEL and ultimately will permit two-color experiments throughout the visible and near infrared. A mid-infrared Ti:Sapphire system is in development. In addition to their potential use in two-color experiments with the FEL, these lasers are being used in stand-alone experiments at the Center.

A high resolution Fourier Transform Infrared Spectrometer, a Bruker IRS-113v spectrometer, has been loaned to the Center by Fisk University. The useful spectral range of this instrument is 5000 cm^{-1} to 10 cm^{-1}. A spectrophotometer purchased by the Center extends spectral coverage to the visible.

	Mid-IR FEL	Far-IR FEL
1992		
	Install undulator and e-beamline	
1993	Test e-beamline	
	Install optical cavity	Install undulator and e-beamline
	First lasing	Test e-beamline
	Install beam transport	Modify undulator
	Operational FEL	Test e-beamline
		Install optical cavity
1994		Attempt lasing
		Increase beam current
		First lasing

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Klystron fabrication: The klystrons that power our superconducting linac structures are now more than 20 years old. These klystrons were fabricated in our laboratory and have been processed many times over the years. They are near the end of their useful life. Since the capability to fabricate new klystrons no longer exists in the laboratory, we have contracted for new klystrons from a commercial source. We expect delivery of the klystrons in 1995.

STANFORD FEL CENTER PUBLICATIONS

- Stanford FEL Center Facilities
- FEL and Accelerator Science
- Solid State and Surface Science
- Molecular Materials and Chemistry
- Biophysics
- Medical Science
- FEL Center Technical Notes

Stanford FEL Center Facilities

CTR1. *The Stanford Picosecond FEL Center,* R. L. Swent, H. A. Schwettman and T. I. Smith, Short Wavelength Radiation Sources, P. Sprangle, Editor, Proc. SPIE **1552**, 24 (1991).

CTR2. *Facilities at the Stanford Picosecond FEL Center*, T.I. Smith, H.A. Schwettman, K.W. Berryman and R.L. Swent, FEL Spectroscopy in Biology, Medicine, and Materials Science, H.A. Schwettman, Editor, Proc. SPIE **1854**, 23 (1993).

CTR3. *The Stanford FEL Center*, H. A. Schwettman, T. I. Smith and R. L. Swent, Nucl. Instr. and Meth. **A341**, ABS 19 (1994).

CTR4. *User Issues at the Stanford Picosecond Free Electron Laser Center*, T. I. Smith, The 6th International Symposium on Advanced Nuclear Energy Research: Innovative Laser Technologies in Nuclear Energy, (Japan Atomic Energy Research Institute, Mito, Japan, March 1994)

CTR5. *FEL Applications in the Infrared,* H. A. Schwettman, Symposium on Ion and Laser Processing for Advanced Materials, in commemoration of the opening of the KEIHANNA SCIENCE CITY (Osaka, Japan, October 1994)

CTR6. *FEL Center User Diagnostics and Control,* K. W. Berryman, B. A. Richman, H. A. Schwettman, T. I. Smith, and R. L. Swent, Nucl. Instr. and Meth. (accepted for publication).

CTR7. *A Flexible Far-Infrared FEL User Facility,* K. W. Berryman and T. I. Smith, Nucl. Instr. and Meth. (accepted for publication).

FEL and Accelerator Science

FEL1. *Intense Low Emittance Linac Beams for Free Electron Lasers,* T. I. Smith, 1986 Linear Accelerator Conference Proceedings, ed. G. A. Loew, SLAC-Report **303**, 421 (1986).

FEL2. *Development of the SCA/FEL for use in Biomedical and Materials Science Experiments,* T. I. Smith, H. A. Schwettman, R. Rohatgi, Y. Lapierre and J. Edighoffer, Nucl. Instr. and Meth. **A259**, 1 (1987).

FEL3. *A Compact Energy Recovered FEL for Biomedical and Materials Science Applications,* R. Rohatgi, H. A. Schwettman and T. I. Smith, Proceedings of the 1987 Particle Accelerator Conference, eds. E. R. Lindstrom and L. S. Taylor, IEEE Cat. No. **87CH2387-9**, 230 (1987).

FEL4. *Experimental Investigation of Low Frequency Modes of a Single Cell RF Cavity,* S. Fornaca, H. Boehmer, J. A. Edighoffer, A. Maschke, G. R. Neil, J. L. Orthel, M. Rhodes, C. E. Hess, H. A. Schwettman and T. I. Smith, Proceedings of the 1987 Particle Accelerator Conference, eds. E. R. Lindstrom and L. S. Taylor, IEEE Cat. No. **87CH2387-9**, 1818 (1987).

FEL5. *Report of the Working Group on Electron Linac Guns at the ICFA Workshop on Low Emittance Beams,* T. I. Smith, Proceedings of the ICFA Workshop on Low Emittance e^--e^+ Beams, eds. J. B. Murphy and C. Pelligrini, BNL **52090**, 125 (1987).

FEL6. *The SCA/FEL Program: Operation in the Infrared, Visible and Ultraviolet,* R. Rohatgi, H. A. Schwettman, T. I. Smith and R. L. Swent, Nucl. Instr. and Meth. **A272**, 32 (1988).

FEL7. *Visible Free Electron Laser Oscillator (Constant and Tapered Wiggler),* J. A. Edighoffer, G. R. Neil, S. Fornaca, H. R. Thompson , Jr., T. I. Smith, H. A. Schwettman, C. E. Hess, J. Frisch and R. Rohatgi, Appl. Phys. Lett. **52**, No. 19, 1569 (1988).

FEL8. *Two-Color Free Electron Laser Driven by a Radio-Frequency Linear Accelerator,* H. A. Schwettman and T. I. Smith , J. Opt. Soc. Am. **B6**, No. 5, 973 (1988).

FEL9. *The Free Electron Laser,* T. I. Smith and H. A. Schwettman, First International Conference on Optoelectronics (Kobe, Japan, November 1988).

FEL10. *Variable Dispersion Electron Spectrometer for the SCA/FEL,* R. L. Swent and T. I. Smith, 1988 Linear Accelerator Conference Proceedings, CEBAF Report **89-001**, 385 (1989).

FEL11. *Intense Low Emittance Injectors for RF Electron Linacs*, Todd I. Smith, AIP Conference Proceedings 184, Vol. 2, Physics of Particle Accelerators, eds. M. Month and M. Dienes, 1543 (1989).

FEL12. *Time-Dependent Measurements on the SCA/FEL*, J. C. Frisch and J. E. Edighoffer, Nucl. Instr. and Meth. **A296**, 9 (1990).

FEL13. *Status of the SCA/FEL*, T. I. Smith, J. C. Frisch, R. Rohatgi, H. A. Schwettman and R. L. Swent, Nucl. Instr. and Meth. **A296**, 33 (1990).

FEL14. *The Variable-Dispersion Spectrometer at the SCA/FEL*, R. L. Swent, J. C. Frisch and T. I. Smith, Nucl. Instr. and Meth. **A296**, 736 (1990).

FEL15. *Time Dependent Measurements on the Superconducting Accelerator Free Electron Laser*, J.C. Frisch, Ph. D. dissertation, Stanford University (1990).

FEL16. *Observation of Anomalous Power Loss in an FEL*, J. C. Frisch, R. L. Swent and T. I. Smith, Nucl. Instr. and Meth. **A304**, 21 (1991).

FEL17. *Applications of Wavelength Agility in an FEL Facility,* R. L. Swent, K. W. Berryman, H. A. Schwettman and T. I. Smith; Nucl. Instr. and Meth. **A304**, 272 (1991).

FEL18. *Facilities for Using the FEL as a Research Tool,* T. I. Smith and H. A. Schwettman, Nucl. Instr. and Meth. **A304**, 812 (1991).

FEL19. *Fabrication Methods of the Superconducting Injector Cavities for the Stanford University Free Electron Laser*, A. Marziali, H. A. Schwettman, J.G. Hatmaker, M. W. Hiller, H.G. Campbell, R. Sinko, M.W. Hamilton C.C. Coghill, R. Dunham, J. L. Light and C. Allcock, IEEE Trans. Magn. **27**, No. 2, 1916 (1991).

FEL20. *The Surface Impedance of Superconductors and Normal Conductors: the Mattis-Bardeen Theory,* J. P. Turneaure, J. Halbritter and H. A. Schwettman, Journal of Superconductivity **4,** No. 5, 341 (1991).

FEL21. *Instrumentation and Diagnostics for Free Electron Lasers*, T. I.Smith, AIP Conference Proceedings **252**, Particles and Fields Series **46**, eds W. Barry and P. Kloeppel, 124 (1992).

FEL22. *Optical Modes in a Partially Waveguided Cavity,* Kenneth W. Berryman and Todd I. Smith, Nucl. Instr. and Meth. **A318,** 885 (1992).

FEL23. *The Use of an External Cavity with the SCA/FEL*, P. Haar, I. M. Fishman, T. I. Smith and H. A. Schwettman, Nucl. Instr. and Meth. **A318**, 899 (1992).

FEL24. *Mechanical Modes of Multicell Linac Structures,* A. Marziali and H. A. Schwettman, Proceedings of the 5th Workshop on RF Superconductivity,ed. D. Proch, DESY Report **M-92-01**, 782 (1992).

FEL25. *Structure Fabrication and Control of Higher Order Modes,* A Marziali, H. A. Schwettman and J. G. Hatmaker, Proceedings of the 5th Workshop on RF Superconductivity,ed. D. Proch, DESY Report **M-92-01**, 802 (1992).

FEL26. *Microphonics and RF Stabilization in Electron Linac Structures,* H. A. Schwettman, Proceedings of the 5th Workshop on RF Superconductivity, ed. D. Proch, DESY Report **M-92-01**, 931 (1992).

FEL27. *Microphonic Measurements on Superconducting Linac Structures,* A Marziali and H. A. Schwettman, 1992 Linear Accelerator Conference Proceedings, ed. C. R. Hoffman, AECL-**10728**, 704 (1992).

FEL28. *Structure Tuning and Its Effect on Higher Order Modes,* A Marziali and H. A. Schwettman, 1992 Linear Accelerator Conference Proceedings, ed. C. R. Hoffman, AECL-**10728**, 707 (1992).

FEL29. *RF Linacs for FELs*, H. A. Schwettman, 1992 AECL Linear Accelerator Conference Proceedings, ed. C. R. Hoffman, AECL-**10728**, 275 (1992).

FEL30. *Feedback Stabilization of the SCA/FEL Wavelength,* A Marziali and T.I. Smith, Nucl. Instr. and Meth. **A331**, 52 (1993).

FEL31. *Experimental Test of the SCA/FEL External Cavity*, P. Haar, H.A. Schwettman and T.I. Smith, Nucl. Instr. and Meth. **A331,** 621 (1993).

FEL32. *Wiggler Limited Long Wavelength Operation of an FEL*, K.W. Berryman, T.I. Smith and R.L. Swent, Nucl. Instr. and Meth. **A331,** 69 (1993).

FEL33. *Microphonic Analysis of Cryo-Module Design*, A. Marziali and H. A. Schwettman, Proceedings of the 1993 Particle Accelerator Conference, ed. , IEEE Cat. No. , (1993).

FEL34. *Demonstration of Wavelength Stabilization in a Free Electron Laser,* A. Marziali and T. I. Smith, IEEE J. Quantum Electron. **30**, 2185 (1994).

FEL35. *Measurements of Single-Pulse Spectra of an Infrared FEL*, W. P. Leemans, J. A. Edighoffer and R. L. Swent, Nucl. Instr. and Meth. **A341**, 473 (1994).

FEL36. *Vibrational Analysis of the Tesla Structure*, A. Marziali and H. A. Schwettman, Proceedings of the 6th Workshop on RF Superconductivity, ed. R. M. Sundelin, CEBAF-October 1993, 1192 (1994).

FEL37. *Generation and Measurement of 50-fs (rms) Electron Pulses*, P. Kung, H. Lihn, H. Wiedemann and D. Bocek, Phys Rev. Lett. **73**, 967 (1994).

FEL38. *Microphonics in Superconducting Linear Accelerators and Wavelength Shifting in Free Electron Lasers*, A. Marziali, Ph. D. dissertation, Stanford University (1994).

FEL39. *Synchronization of a Femtosecond Modelocked Ti:Sapphire Laser to the Stanford SCA/FEL,* R.J. Stanley, R.L. Swent and T.I. Smith, Opt. Comm. (accepted for publication).

FEL40. *Time Resolved Study of Sideband Generation and Transition to Chaos on an Infrared FEL*, W. P. Leemans, M. E. Conde, M. J. de Loos, B. van der Geer, R. L. Swent, T. I. Smith and H. A. Schwettman, Nucl. Instr. and Meth. (accepted for publication).

FEL41. *Sub-Picosecond FEL Micropulse Length and Electron Bunch Measurements,* E. R. Crosson, K. W. Berryman, H. Lihn, T. I. Smith and H. Wiedemann, Nucl. Instr. and Meth. (accepted for publication).

FEL42. *Wavelength Shifting in the Stanford FEL*, A. Marziali, T. I. Smith and H. A. Schwettman, Nucl. Instr. and Meth. (accepted for publication).

FEL43. *FEL Cavity Length Measurement with an External Laser*, K. W. Berryman, P. Haar and B. A. Richman, Nucl. Instr. and Meth. (accepted for publication).

FEL44. *Temporal Characterization of the Stanford Mid-IR FEL Micropulses by 'Frog'*, B. A. Richman, Nucl. Instr. and Meth. (accepted for publication).

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