MIT Council on Educational Technology (MITCET)

Global Learning Strategic Initiative

University of Mexico Virtual Research Group

Preliminary Proposal by Keith A. Nelson

Department of Chemistry and Harrison Spectroscopy Laboratory, MIT

Executive Summary

A collaboration with the University of Mexico (Universidad Nacional Autónoma de México, or UNAM) through which homebuilt, state-of-the-art experimental apparatus can be accessed remotely for teaching and research use will be established. An MIT UROP student will play a key role in setting up the networked system, working with counterparts at UNAM to establish remote access, and seeing the project through at the UNAM campus. The experimental apparatus is based on research in the P.I.'s group at MIT, and it is used for an existing outreach program for Boston area high school students. The remotely accessed experimental station will be a first step toward a large-scale cyber-enabled laboratory for which major funding has been requested in a pre-proposal to the NSF Cyber-Enabled Discovery and Innovation (CDI) program. The large-scale project also will establish a "virtual research group" including UNAM as well as high school, four-year college, and private sector initial partners within the U.S. The present effort and the larger one will involve close collaboration with the iLab Project based at MIT's Center for Educational Computing Initiatives (CECI). The experimental measurements are of interest in physical chemistry, solid state physics, materials science and engineering, and mechanical engineering disciplines. They are relevant generally to advanced materials characterization, and they are relevant specifically to thermoelectric materials research currently under way (with MITEI support) in a collaboration between the P.I. and Professor Gang Chen of the MIT Department of Mechanical Engineering. Our overall effort at remote access is aimed at broad transformation of access to world-class experimental science. It will become possible for institutions and individuals around the world to participate directly and substantively in real science, including experimental design, experimental execution, data analysis, and publication. Our partnership with UNAM will be a modest first step through which teaching and research will be undertaken using remote access to the MIT laboratory apparatus.

Project Description

Outreach, Teaching, and Research

The outreach experimental station is organized around a time-resolved laser spectroscopy measurement in which crossed laser pulses are used to generate acoustic waves in a sample and the time-dependent acoustic oscillations are monitored through diffraction of probe laser light. See Fig. 1a. From the measurement, the frequency, speed, and attenuation rate of the acoustic wave are extracted. On longer time scales, thermal diffusion is observed as well. The measurement has myriad applications spanning multiple disciplines of science and engineering, including fundamental study of viscoelastic fluids (see Fig. 1b), liquid-glass transitions, and structural phase transitions; determination of bulk and thin film mechanical properties (elastic and loss moduli); characterization of film thickness and adhesion to or delamination from a substrate; and determination of acoustic phonon mean free paths and contributions to heat transport in thermoelectric materials whose thermal conductivities must be minimized for optimum performance. In our high school outreach program, students spend several afternoons at MIT depositing metallic thin films (at CMSE) and characterizing film stiffness and thickness using our experimental system. In the process they learn about modern optics including interference (they cross two laser pulses to form an interference pattern whose geometry determines the acoustic wavelength) and diffraction; advanced materials and fabrication methods; time scales for physical phenomena and length scales for natural and fabricated structures; and modern optical measurement methods. At the university teaching level, the lessons will include wave mechanics in bulk materials and thin film waveguides; polymer film processing and viscoelasticity; solid-state phase transformations; and acoustic phonon mean free paths and heat transport. Research also will involve these topics. The experimental geometry is versatile and many other properties may be explored subsequently.

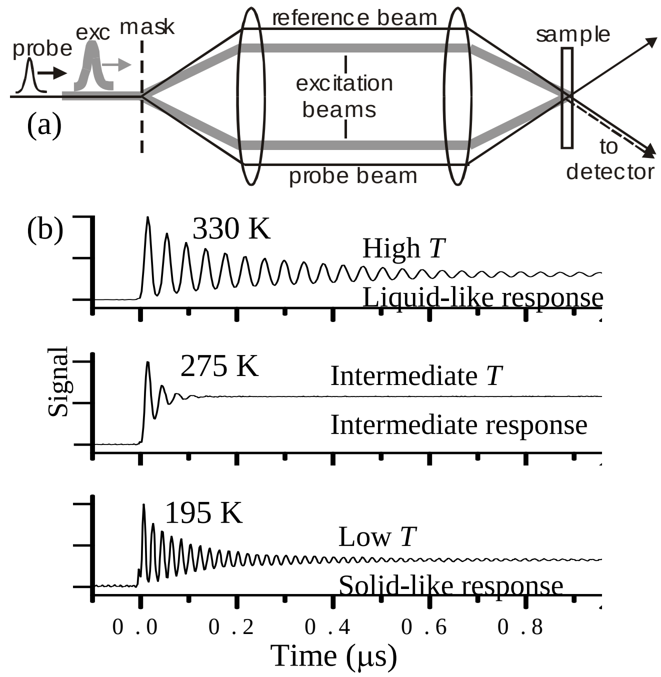

Fig. 1. (a) Transient grating photoacoustic measurement setup. Diffractive optic (phase mask) generates the two excitation beams, which are crossed at the sample to suddenly heat it and generate a spatially periodic thermoelastic response. The probe and reference beams are used to monitor the time-dependent sample response through diffraction with optical heterodyne detection. Many mask patterns with different periods are etched onto a single glass substrate for rapid acoustic wavelength and frequency tuning. (b) Data recorded from bulk glycerol showing increased acoustic damping in the viscoelastic regime and showing increased acoustic frequency and speed as the sample is cooled from liquid to glass. Thermal diffusion is observed on slower time scales.

<u>Project context and plan</u>

A pre-proposal (available upon request) for expansion of the lab facilities to include additional experimental stations and to enable remote access for multiple outside users, based on the CECI iLabs Shared Architecture middleware, has been submitted to NSF. A four-year program with a budget of $2.25M, including a dedicated Laboratory Manager and extensive time commitments on the part of CECI personnel, has been proposed. Our present objectives are more modest, but we believe that the proposed collaboration with UNAM will demonstrate a crucial first demonstration that state-of-the-art, homebuilt research equipment can be remotely accessed for outreach, teaching, research, and practical metrology by a wide range of outside institutions and individuals. A strong MIT commitment toward our objectives may help persuade NSF to approve a full proposal if it is requested.

We will set up remote access with our collaborators at UNAM (Profs. Victor Romero-Rochin and Jorge Peon in the UNAM Institutes of Physics and Chemistry respectively) in three stages. First, starting summer 2009, students at MIT (a UROP student and, if his internship application is successful, a visiting student from Ukraine) will work under the direction of Nelson group graduate students and a CECI Project Manager, Philip Bailey, to set up the software and hardware needed at MIT and to test the system locally. Second, they will work with counterparts at UNAM to link the lab at MIT with the remote-access locations at UNAM. These two objectives are the first-year milestones. Third (summer 2010 and perhaps IAP 2011) the UROP student and Professor Nelson (a fluent Spanish speaker) will travel to UNAM to work with counterparts there to test the link and to try remote measurements designed for research and teaching in Physics, Chemistry and Engineering programs.

The budget requested is $25,000 for each of two years. About half of this will go toward paying a UROP student for summer, fall and spring terms and IAP each year. The other half will go toward partial payment for Philip Bailey's effort, travel to UNAM, and materials & supplies (computers for the lab and the UROP student's use, software, CCD cameras and optics to optimize remote viewing of the experiment, electronics hardware for interfacing/networking).

Just as public access to scientific and technical information has expanded dramatically over the last 10-20 years, public participation in science and technology will expand similarly during the next 10-20 years. We hope to play a leading role in that transformative change.