

future work will be extended to a 1024 x 1024-pixel device now under development.

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EVERY GOOD VIRTUE YOU EVER WANTED IN A Q-SWITCHED SOLID-STATE LASER AND MORE—MONOLITHIC, DIODE-PUMPED, SELF-Q-SWITCHED, HIGHLY REPRODUCIBLE, DIFFRACTION-LIMITED Nd:YAG LASER. Y. C. Chen¹ and K. K. Lee², ¹Physics Department, Hunter College of CUNY, New York NY 10021, USA, ²Electrical and Computer Engineering Department, University of Colorado, Colorado Springs CO 80933-7150, USA.

The applications of Q-switched lasers are well known, for example, laser radar, laser remote sensing, satellite orbit determination, Moon orbit and "moonquake" determination, satellite laser communication, and many nonlinear optics experiments. Most of the applications require additional properties of the Q-switched lasers, such as single-axial and/or single-transverse mode, high repetition rate, stable pulse shape and pulse width, or ultracompact and rugged oscillators with some or all of the above properties. Furthermore, spacebased and airborne lasers for lidar and laser communication applications require efficient, compact, lightweight, long-lived, stable-pulsed laser sources. Diode-pumped solid-state lasers (DPSSL) have recently shown the potential of satisfying all these requirements.

We will report the operating characteristics of a diode-pumped monolithic self-Q-switched Cr,Nd:YAG laser where the chromium ions act as a saturable absorber for the laser emission at 1064 nm [1]. The pulse duration is 3.5 ns and the output is highly polarized with an extinction ratio of 700:1 [1]. It is further shown that the output is single-longitudinal-mode with transform-limited spectral line width without pulse-to-pulse mode competition [2]. Consequently, the pulse-to-pulse intensity fluctuation is less than the instrument resolution of 0.25% [2]. This self-stabilization mechanism is because the lasing mode bleaches the distributed absorber and establishes a gain-loss grating [3,4] similar to that used in the distributed feedback semiconductor lasers. Repetition rate above 5 KHz has also been demonstrated [3]. Figure 1 shows how compact, simple, and rugged this laser oscillator is. For higher power, this laser can be used for injection seeding an amplifier (or amplifier chain) or injection locking of a power oscillator pumped by diode lasers. We will discuss some research directions on the master oscillator for higher output energy per pulse as well as how to scale the output power of the diode-pumped amplifier (s) to multikilowatt average power.

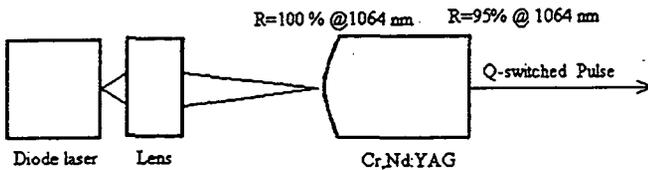


Fig. 1.

References: [1] Li S.-Q. et al. (1993) *Opt. Lett.*, 18, 203. [2] Li S.-Q. et al. (1993) *Opt. Lett.*, 18, April 1 issue. [3] Chen Y. C. et al. (1993) *Opt. Lett.*, 18, in press. [4] Li S.-Q., *Appl. Phys. Lett.*, submitted.

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PLANETARY AND SATELLITE X-RAY SPECTROSCOPY: A NEW WINDOW ON SOLID-BODY COMPOSITION BY REMOTE SENSING. D. L. Chenette¹, R. W. Wolcott¹, and R. S. Selesnick², ¹Lockheed R&D Division, Palo Alto CA 94304, USA, ²Downs Laboratory, California Institute of Technology, Pasadena CA 91125, USA.

The rings and most of the satellites of the outer planets orbit within the radiation belts of their parent bodies, an environment with intense fluxes of energetic electrons. As a result these objects are strong emitters of X-rays. The characteristic X-ray lines from these bodies depend on atomic composition, but they are not sensitive to how the material is arranged in compounds or mixtures. X-ray fluorescence spectral analysis has demonstrated its unique value in the laboratory as a qualitative and quantitative analysis tool. This technique has yet to be fully exploited in a planetary instrument for remote sensing. The characteristic X-ray emissions provide atomic relative abundances. These results are complementary to the molecular composition information obtained from IR, visible, and UV emission spectra. The atomic relative abundances are crucial to understanding the formation and evolution of these bodies. They are also crucial to the proper interpretation of the molecular composition results from the other sensors. The intensities of the characteristic X-ray emissions are sufficiently strong to be measured with an instrument of modest size. Recent developments in X-ray detector technologies and electronic miniaturization have made possible space-flight X-ray imaging and nonimaging spectrometers of high sensitivity and excellent energy resolution that are rugged enough to survive long-duration space missions. Depending on the application, such instruments are capable of resolving elemental abundances of elements from carbon through iron. At the same time, by measuring the bremsstrahlung intensity and energy spectrum, the characteristics of the source electron flux can be determined. We will discuss these concepts, including estimated source strengths, and will describe a small instrument capable of providing this unique channel of information for future planetary missions. We propose to build this instrument using innovative electronics packaging methods to minimize size and weight.

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POLARIMETRIC MULTISPECTRAL IMAGING TECHNOLOGY. L.-J. Cheng, T.-H. Chao, M. Dowdy, C. Mahoney, and G. Reyes, Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, USA.

The Jet Propulsion Laboratory is developing a remote sensing technology on which a new generation of compact, lightweight, high-resolution, low-power, reliable, versatile, programmable scientific polarimetric multispectral imaging instruments can be built to meet the challenge of future planetary exploration missions.

The instrument is based on the fast programmable acousto-optic tunable filter (AOTF) of tellurium dioxide (TeO₂) that operates in

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the wavelength range of 0.4–5 μm . Basically, the AOTF multispectral imaging instrument measures incoming light intensity as a function of spatial coordinates, wavelength, and polarization. Its operation can be in either sequential, random access, or multiwavelength mode as required. This provides observational flexibility, allowing real-time alternation among desired observations, collecting needed data only, minimizing data transmission, and permitting implementation of new experiments. These will result in optimization of the mission performance with minimal resources.

This instrument can be used for two types of applications for future planetary exploration missions. First, the instrument is placed on a flight platform for mapping the interesting features on the surface and in the atmosphere of a planet or a moon. For example, this instrument is an excellent candidate as a visible-infrared imaging spectrometer for the Lunar Observer and a polarimetric imaging spectrometer for the Pluto Fast Flyby. The same instrument can be used to investigate atmospheric physics and chemistry of Jupiter and Saturn. In the other application, the instrument is used on a rover or a surface package on Mars and the Moon as an intelligent vision instrument for searching, identifying, mapping, and monitoring geological features, characterizing atmospheric contents and their time variability, as well as collecting valuable samples. For example, these instrument applications will support major scientific objectives of the Mars Environmental Survey (MESUR) program and the Evolutionary Mars Sample Return Program.

In the past we built two AOTF imaging spectrometer breadboard systems covering visible to short-wavelength infrared ranges and successfully demonstrated capabilities for identifying minerals and mapping content distributions, characterizing botanical objects, and measuring polarization signatures. In addition, we demonstrated the use of an optical fiber bundle as an image transfer vehicle in the AOTF system with the objective of developing an AOTF system with a flexible observation head for rover applications.

Recently we completed a polarimetric multispectral imaging prototype instrument and performed outdoor field experiments for evaluating application potentials of the technology. We also investigated potential improvements on AOTF performance to strengthen technology readiness for applications. This paper will give a status

report on the technology and a prospect toward future planetary exploration.

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A REMOTE LASER-MASS SPECTROMETER FOR DETERMINATION OF ELEMENTAL COMPOSITION.

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Determination of the elemental composition of lunar, asteroid, and planetary surfaces is a major concern for science and resource utilization of space. The science associated with the development of a satellite or lunar rover laser-mass spectrometer instrument is presented here. The instrument would include a pulsed laser with sufficient energy to create a plasma on a remote surface. Ions ejected from this plasma travel back to the spacecraft or rover, where they are analyzed by a time-of-flight mass spectrometer, giving the elemental and isotope composition. This concept is based on the LIMA-D instrument onboard the former Soviet Union Phobos-88 spacecraft sent to Mars.

A laser-mass spectrometer placed on a rover or satellite would substantially improve the data return over alternative techniques. The spatial resolution would be centimeters, and a complete mass spectrum could be achieved in one laser shot. An experiment is described (Fig. 1) that demonstrates these features.

A 400 mJ Nd:YAG laser is focused, to an intensity of 10^{11} w/cm², onto a Al, Ag, Cu, Ge, or lunar simulant target. A plasma forms from which ions are ejected. Some of these ions travel down an 18-m evacuated flight tube to a microchannel plate detector. Alternatively, the ions are captured by an ion trap where they are stored until pulsed into a 1-m time-of-flight mass spectrometer, giving the elemental composition of the remote surface. A television camera monitors the plasma plume shape, and a photo diode monitors the temporal plasma emission. With this system, ions of Al, Ag, Cu, Ge, and lunar simulant have been detected at 18 m. The mass spectrum from the ion trap and 1-m time-of-flight tube will be presented. Figure 2 shows ions of Al (1803 ev), Cu (1483 ev), Ag (1524 ev),

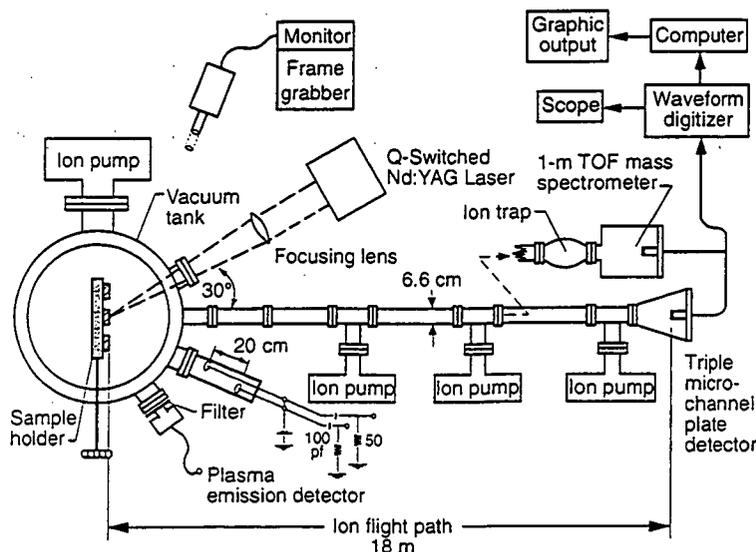


Fig. 1.