Discovery at the Interface of Science and Engineering: **Science Matters!**

Materials Science and Technology
Optical Sciences

Microlasers

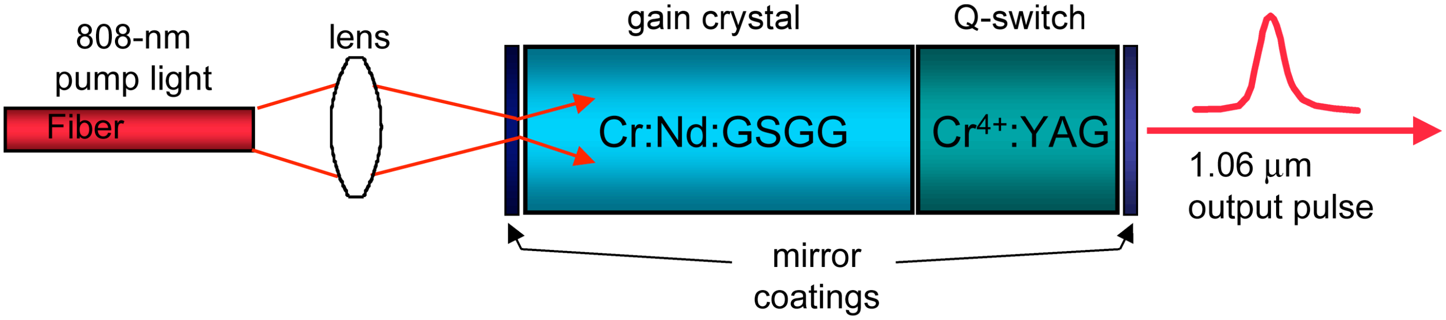

Figure 1: Schematic diagram of a laser-diode-pumped microlaser. Pump light from a fiber-coupled laser diode is imaged into the end of the microlaser. The microlaser consists of a gain crystal bonded to a passive Q-switch crystal. The end faces are polished flat and parallel and mirror coatings are deposited directly on the faces to form a monolithic laser cavity.

> *Versatile lasers fill unique requirements in many diverse applications*

Diode-laser-pumped passively Q-switched microlasers are efficient, rugged, and compact lasers that have become critical components in Sandia's programs in optical-based firing sets, remote sensing (LIDAR, LIght Detection And Ranging), molecular spectroscopy, and other applications. For example, microlasers can be used to optically trigger high-voltage switches in firing sets, thereby providing improved safety from lightning and static discharge. Also, microlasers enable extremely compact LIDAR systems which can be used to map the size, shape, location, and composition (via spectroscopic signals, such as absorption, Raman scattering and laser induced fluorescence) of clouds or aerosols. Other potential applications include using microlasers in very compact laser ranging (LADAR, LAser Detection And Ranging) instruments. LADAR detects hard-target backscatter from solid objects, and is used for determining range to targets or 3-D imaging of remote scenes.

A typical microlaser, illustrated in Figure 1, is pumped from one end by a laser diode (often fiber coupled) to maximize the spatial overlap between the pumped volume and the lasing mode and thereby maximize its overall efficiency. The microlaser itself consists of a gain crystal (Cr:Nd:GSGG in this example) diffusion bonded to a saturable absorber crystal (Cr^{4+}:YAG for 1-µm-output lasers) that serves as a passive Q-switch. Both end faces of this composite crystal are polished flat and parallel to one another with dielectric mirror coatings on the faces to form a monolithic laser cavity. When the laser is pumped, the saturable absorber prevents laser oscillation until the gain in the laser crystal is high enough to saturate the absorbing transition, resulting in the emission of a short (~1-ns-long) Q-switched pulse of light. These miniature passively Q-switched lasers can be operated single-shot or repetitively pulsed at rates exceeding 20 kHz.

The versatile miniature lasers have been designed to produce nanosecond-long optical pulses with excellent beam quality and high spectral purity that are ideal for efficient nonlinear optical frequency conversion to the ultraviolet or the infrared, enabling the miniaturization

For more information:
Technical Contact:
Randy Schmitt
505-844-9519
schmitt@sandia.gov

Science Matters Contact:
Alan Burns, Ph.D
505-844-9642
aburns@sandia.gov

Sandia National Laboratories
LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

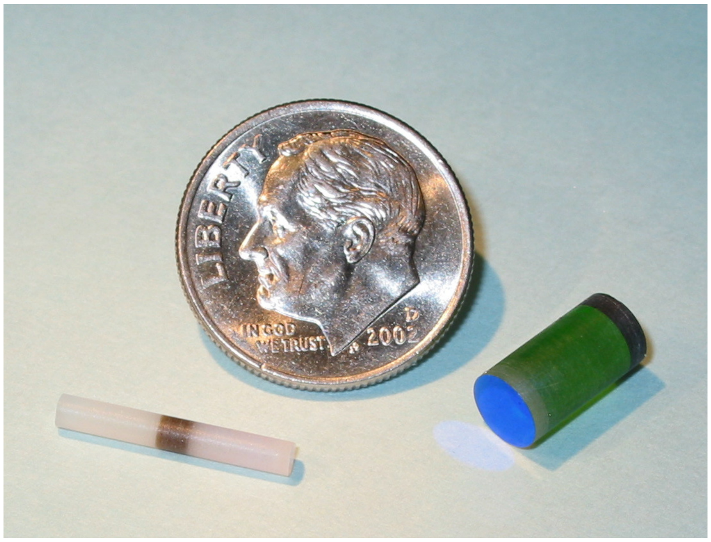

Figure 2: Examples of Sandia-designed microlasers. The microlaser on the left is a Nd:YAG laser designed to produce high-energy (>200 µJ/pulse) single-frequency output for spectroscopic applications. The microlaser on the right is a Cr:Nd:GSGG laser which is fabricated from radiation-hard materials and is intended for weapons applications such as optical triggering of sprytrons.

of spectroscopic-based instrumentation and compact LIDAR systems. Many of the microlasers have output wavelengths, pulse energies, and pulse durations that are not available commercially, but are required and optimized for specific Sandia applications. For example, we designed and built a microlaser from radiation-hard Cr:Nd:GSGG and Cr^{4+}:YAG for optically triggering sprytron tubes with with as little as a few microjoules of Q-switched laser energy. This microlaser, shown in Figure 2, may eventually be engineered into an all-optical firing set, leading to improved safety of weapons firing systems from lightning and static discharge. We are also exploring using microlasers to directly initiate explosive materials. potentially eliminating the need for an electrical detonator altogether.

We have also developed a single-longitudinal-mode, high-energy (up to 200 µJ/pulse) Nd:YAG microlaser (also shown in Figure 2) for use in compact spectroscopic-based instrumentation. The 1064-nm output from this microlaser has been efficiently converted to 355 nm and 266 nm for use in laser-induced-fluorescence instruments used for research on detection of biological aerosols and other materials. This same microlaser has been frequency converted to 3.27 µm for use in a hand-held methane imager designed for short-range (1- 2 m) standoff detection of leaks in natural gas plumbing. Here, the laser was optimized to operate in a double-pulse mode, emitting a pair of 2-ns-long pulses separated by 100 µs (with an overall repetition rate of ~2 kHz) as required to perform a differential absorption measurement.

As part of a fiber laser project, we developed a family of Yb:YAG microlasers with pulse lengths from 0.5 ns to 1.0 ns and single-longitudinal-mode operation at repetition rates up to 19.4 kHz to use as seed sources for Yb-doped fiber amplifiers. The 1030-nm output of Yb:YAG more closely matches the gain peak in Yb-doped fiber than the ~1060-nm output of Nd-based lasers and results in more efficient pulsed fiber laser systems. Using the 1030-nm microlaser as a seed source, we demonstrated a 40% increase in pulse energy compared with 1062.4-nm source typically used.

As the demand for more compact and field-able laser-based instrumentation increases, the need for more specialized microlasers will also increase. Sandia will continue to lead in developing microlasers to meet the unique needs of research and development of optical firing sets, miniature sensors, and other national security applications.

References:

R. L. Schmitt, *"Monolithic passively Q-switched Cr:Nd:GSGG microlaser,"* Proc. SPIE, **5871**, 587105 (2005).

R. L. Schmitt and B. T. Do, *"Design and Performance of a High-Repetition-Rate Single-Frequency Yb:YAG Microlaser,"* Proc. SPIE, **6871**, 687105 (2008).

Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2008-5080P

National Nuclear Security Administration

08/2008