As the electron concentration in this region becomes such that it corresponds to Spitzer’s conductance, it is assumed that the channel has propagated for a certain distance. Balance equations that describe the nonlinear mediated plasma-chemical reactions. Rate constants for these reactions are determined by taking into account the electron velocity distribution obtained by solving the Boltzmann kinetic equation.

The predicted times of channel formation are compared to experimental data obtained for a wide range of initial conditions. The comparison shows a rather good qualitative and quantitative agreement. (12 min)

Friday 29 April 1988
MORNING

CALIFORNIA AVALON C

9:30 AM Lanthanide Series Lasers and Nonlinear Effects

Steve Guch, Jr., GTE Government Systems, Presider

FE1 Fifty-two percent efficient second harmonic generation of a cw-diode-pumped laser using a monolithic external ring cavity

WILLIAM J. KOZLOVSKY, C. D. NABORS, ROBERT L. BYER, Stanford University, Stanford, CA 94305.

There has been much recent interest in the development and applications of diode-laser-pumped solid-state lasers. Efficient frequency doubling of these lasers requires some method to increase the intensity in the doubling crystal over that available from the diode pump, since the diode pump intensities are relatively small. Diode-pumped solid-state lasers have been Q-switched or mode-locked to produce high-peak-power outputs that can be efficiently frequency doubled. Approaches to cw second harmonic generation have concentrated on intracavity frequency doubling, where advantage is taken of the high circulating intensity present inside the laser resonator. Although this method leads to good overall efficiencies, the output of these lasers is generally in several axial modes, which results in large amplitude fluctuations at the second harmonic.

We have investigated frequency doubling the output of a cw single-axial-mode frequency-stable nonplanar ring Nd:YAG laser to the visible using external cavity resonant second harmonic generation. In this method, the laser output is placed in an external resonator designed to enhance either the fundamental and/or the second harmonic field for increasing the doubling efficiency. For our experiments we chose MgO:LiNO₃ because of (1) its large nonlinearity for noncritical 90° phase matching and (2) its low loss at 1.06 µm, important for resonating the fundamental.

A monolithic resonator was fabricated by polishing the ends of a 1.25-cm-long crystal of MgO:LiNO₃ (x axis along length) with 1-cm radius of curvatures. In addition, the 2-face of the crystal was polished perpendicular to these ends. The crystal thus formed a travelling-wave ring resonator, which offers the advantage of single-direction second harmonic output. A monolithic design, where thin-film coatings were applied directly to the ends of the crystal, ensured low losses and resonator stability. The output end was coated to be a high reflector at 1.06 µm, and the input end was coated 98.3% reflecting to impedance match the crystal for maximizing the coupling of the fundamental into the cavity.

The experimental setup is shown in Fig. 1. The output of the diode-laser-pumped nonplanar ring laser was spatially mode matched into the external resonator with a pair of lenses. The oven containing the monolithic resonator was held at 107°C to provide proper phase matching. The resonator’s optical length was controlled electrooptically using the rate of change of applying a voltage across the axis. This electrooptic tuning enabled the external cavity to be locked on resonance with the laser output frequency.

The output power of the doubler at 532 nm as a function of incident power is shown in Fig. 2. At the maximum laser output, 24.5 mW of cw second harmonic were generated from the incident fundamental power of 47.4 mW, for an conversion efficiency of 52%. Thus external monolithic second harmonic doubling is an efficient source of stable single-axial-mode output at the second harmonic.

(12 min)


FE2 Violet cw neodymium upconversion laser


Continuous-wave laser operation in the violet of 390 nm has been achieved on the 4D₂ₓ → 4F₂ₓ transition in LiF·Nd⁵⁺ at temperatures of <90 K. Two different upconversion pumping mechanisms resulted in laser action: (a) sequential two-step absorption of an IR (780-nm) photon and a yellow (580-nm) photon by the Nd³⁺ ions; (b) cooperative energy transfer upconversion following the absorption of one yellow (578-nm) photon per Nd³⁺ ion. At temperatures near 20 K up to 12-mW power at 390 nm was obtained using pump powers of several hundred milliwatts from two cw dye lasers and conservative 1% output coupling. At 77 K, the output power decreased to ~4 mW.

Nonlinear upconversion excitation schemes based on the absorption of two (or more) pump photons can be an attractive approach for pumping visible solid-state lasers. Following an initial observation of pulsed stimulated emission by upconversion pumping of Ho³⁺ and Er³⁺ ions in 1971, green upconversion laser operation at 550 nm was recently observed in YAlO₃:Er³⁺ and YLiF₄:Er³⁺, using dye lasers near 600 nm as pump sources. The possibility of an upconversion laser in YLiF₄:Nd³⁺ at 412 nm was discussed recently, but no laser was reported.

(12 min)

FE3 Effect of upconversion on 2.7-µm laser action in Er³⁺


Lasing on the 5I₁₁₁ → 5I₁₁₀ transition in Er³⁺ is of interest both for medical applications and for optical communications in heavy metal fluoride glass (HMF) fibers. During recent attempts in our laboratory to obtain lasing at 2.7 µm in Er-doped HMF fiber, we observed strong green fluorescence when pumping at either 798 or 647 nm. The question arose as to whether this upconversion would prevent or limit the efficiency of laser action. To characterize quantitatively this effect, the absolute efficiency of upconversion was measured, and the mechanism of upconversion was verified by a combination of spectral and temporal measurements.

Measurements were made on a bulk sample of Er-doped fluorozirconate glass (ZBLA). The 1% Er:ZBLA sample in the 647-670-nm range exciting the F₂ level. The absolute upconversion efficiency was measured in a calibrated integrating sphere with an optical filter to block the pump beam and pass the green fluorescence. Upconversion efficiency is defined here as the ratio of emitted power to absorbed power. The absorbed power was determined from the emission spectrum, and the absorption coefficient measured on a spectrophotometer. With 48 mW of pump light at 652 nm focused to a spot of 50-µm diameter, the absolute upconversion efficiency was measured to be 0.5%. The absorption cross section at that wavelength is σₐ = 5.3 x 10⁻²⁵ cm².

There are two distinct processes which could give rise to the observed upconversion. The first is energy transfer upconversion (ETU), which in-
Fig. 1. Energy level diagrams of the Nd$^{3+}$ ion showing upconversion pumping and laser transitions: (a) upconversion by two-step absorption using an IR and a visible pump laser; (b) cooperative energy transfer upconversion between two ions, one in the $^4G_{5/2}$ state and one in $^4F_{3/2}$. (Not all levels of Nd$^{3+}$ are shown.)

Fig. 2. Upconversion laser output as a function of pump power: (a) two-step excitation with the IR power fixed and yellow power varied and vice versa; (b) single-pump laser at 577.7 nm.