11-mJ, 15-Hz single-frequency diode-pumped Q-switched Er, Yb:phosphate glass laser

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A single-frequency diode-pumped Q-switched Er, Yb:phosphate glass laser that oscillates at an eye-safe 1.54-μm wavelength has been developed for use in coherent Doppler lidar. A maximum TEM_{00}-mode Q-switched output energy of 10.9 mJ and a relatively long pulse width of 228 ns were obtained at a repetition rate of 15 Hz by use of a modified 2-m-long telescopic cavity. Frequency stability of as high as ±1.9-MHz standard deviation and a side-mode suppression ratio of more than 30 dB were also achieved. © 2001 Optical Society of America

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Remote sensing of wind velocity is useful for weather forecasts or air-safety precautions for air traffic. A coherent Doppler lidar (CDL) is now recognized as a promising sensor for real-time wind-velocity detection in clear air conditions. For pulsed lasers used in CDL, stable single-frequency oscillation, a relatively long pulse width, linearly polarized output, and a high repetition rate are required. In early works the possibilities of the CDL were studied by use of pulsed CO_2 lasers.[1] In recent years, diode-pumped 2-μm pulsed lasers such as Ho, Tm:YAG and Tm:YAG lasers were used to improve the efficiency and compactness of CDL systems.[2–4] The wavelength range of 1.5 μm has attractive characteristics compared with the 2-μm range. The single-pulse maximum permissible exposure to the 1.5-μm range for human eyes is 10 times higher than that for the 2-μm range.[5] A shorter wavelength provides a small product of range resolution Δx and velocity resolution Δv, related by $\Delta x \Delta v = c\lambda/3.4\pi$,[6] where λ is the operating wavelength and c is the speed of light. There are fewer absorption lines for the molecules in the atmosphere in the 1.5-μm range than in the 2-μm range. Optical fiber components, laser sources, and detectors for the optical fiber communications are easily available Despite these advantages, CDLs operated at 1.5 μm have not been developed because of the lack of a pulsed laser that is suitable for use in a CDL. Of the 1.5-μm solid-state laser materials, Er, Yb:glass is the most popular and has been studied for a long time. However, the relatively small emission cross section and low thermal conductivity of Er, Yb:glass have prevented researchers from obtaining high-energy Q-switched output with high repetition rates or high-average-power operation. High-energy Q-switched operation with 45-mJ output energy and a 1-Hz repetition rate[7] and high-repetition operation with 6-mJ output energy and a 50-Hz repetition rate[8] were demonstrated by use of frustrated total internal reflection Q-switching. However, these laser outputs were obtained in multitransverse- and multilongitudinal-mode operation, the pulse widths were a few tens of nanoseconds, and the output beams were not polarized. Single-frequency Q-switched operation with 1-mJ power and a 1-Hz repetition rate by use of an injection-seeding technique[9] and an intracavity grating were also demonstrated.[10] The repetition rate was low, and the frequency was not stabilized. Thus, to our knowledge, a 1.5-μm pulsed laser suitable for CDL has not been reported. In this Letter we report what is to our knowledge the first frequency-stabilized diode-pumped Er, Yb:glass Q-switched laser, which oscillates at a wavelength of 1.54 μm.[11–13]

For Er, Yb:glass laser material, high-intensity pumping is required for high gain and, consequently, efficient laser oscillation. Figure 1 shows a configuration of a developed pumping module composed of two pumping heads. Each pumping head is composed of an Er, Yb:glass square rod, four 6-bar stacked diode arrays, two focusing prisms, and two heat sinks. The active material is Yb–sensitized Er phosphate laser glass, Kigre QX/Er, with ion concentrations of $Er^{3+} = 6 \times 10^{19}$ ions/cm^3 and $Yb^{3+} = 15 \times 10^{20}$ ions/cm^3. The size of the square rod is 1.7 mm × 1.7 mm and 10 mm long. A pair of parallel side surfaces is placed in contact with heat sinks by use of indium foil to remove heat generated in the rod. The diode arrays are also mounted on the water-cooled aluminum heat sinks. The wavelengths of the diode arrays are experimentally adjusted for maximum gain by the water temperature. The rod is pumped from the other two side surfaces, which are antireflection

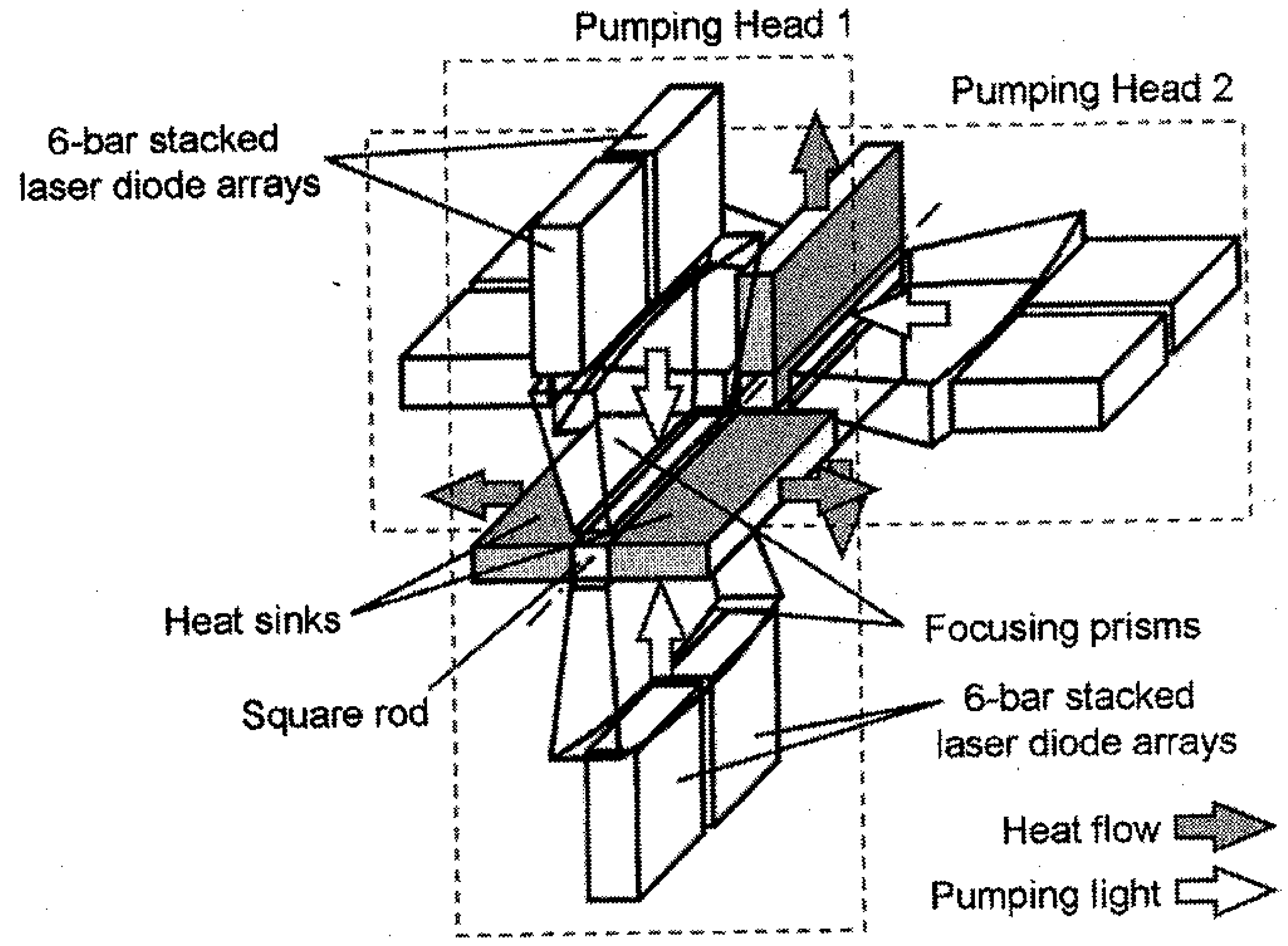

Fig. 1. Configuration of a developed pumping module composed of two pumping heads, which realizes high-intensity pumping for Er, Yb:glass laser material.

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