Picosecond pulses from a cryogenically cooled, composite amplifier using Yb:YAG and Yb:GSAG

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A cryogenic Yb amplifier using two laser materials, $Gd_3Sc_2Al_3O_{12}$ and $Y_3Al_5O_{12}$ (YAG), has been used to obtain 70 W average power at 5 kHz pulse repetition frequency; the output was compressed to 1.6 ps, compared with an input compressible to 1.4 ps. The gain broadening obtained by combining two media enables shorter pulses than using Yb:YAG alone but retains the power-scaling advantages of cryogenic Yb:YAG.

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Cryogenic cooling of Yb-doped laser gain media has proven to be an effective approach to scaling the average power of solid-state lasers while maintaining good beam quality [1,2]. This approach has enabled the demonstration of a 287 W average-power Yb:$Y_3Al_5O_{12}$ (YAG) system operating at 78 MHz pulse repetition frequency (PRF) with 5.5 ps pulses [3] and an 80 W average-power system operating at 2 kHz PRF with pulses compressible to ~15 ps [4]. However, at cryogenic temperatures, the Yb:YAG gain bandwidth is narrower than at room temperature and thus limits the minimum pulse width to a few picoseconds. Two approaches to achieving shorter pulses in these cryogenic Yb-doped systems are using gain media with larger gain bandwidth, such as Yb:$LiYF_4$ (YLF) [5,6], and using Yb:YAG in conjunction with another Yb-doped gain medium to provide a larger composite bandwidth. This latter approach of using multiple gain media [7–12] is attractive because it more directly leverages existing high-power cryogenic Yb:YAG technology, and we use it here in a high-power pulsed system capable of 1.6 ps pulses at 5 kHz PRF with 60 W average power. In this system, the second gain medium was Yb:$Gd_3Sc_2Al_3O_{12}$ (GSAG). GSAG was chosen because its properties are similar to those of YAG, both being oxide garnets, and its gain peak at cryogenic temperatures is offset from, but overlaps with, the gain spectrum in YAG. Many other Yb-doped gain media may also be attractive for use with YAG. Similar performance in average power and pulse width has been demonstrated using a room-temperature Yb:YAG thin-disk regenerative amplifier [13] with 150 round trips; however, these thin-disk amplifiers have relatively low single-pass gain, which can lead to practical difficulties with deterministic chaos in regenerative amplifiers with large numbers of round trips. The higher gain in this cryogenic amplifier enables scaling to this performance while avoiding deterministic chaos effects by reducing the required number of passes.

The absorption and gain spectra of Yb:GSAG at 80 K are shown in Fig. 1, and, not surprisingly, the main features are similar to those of cryogenic Yb:YAG. As with Yb:YAG, the Yb:GSAG main absorption band around 940 nm remains sufficiently broad at low temperatures that only loose requirements exist for the pump spectra; pumping on the 969 nm absorption feature, however,

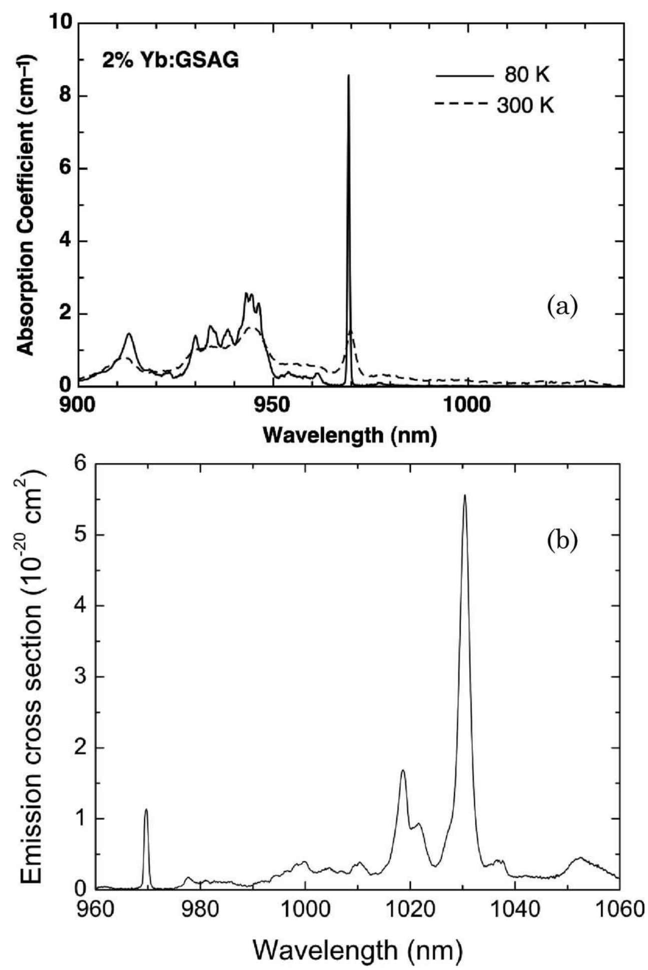

Fig. 1. Absorption and emission spectra of Yb:GSAG. (a) Absorption coefficient for 2% Yb doping at 300 K and 80 K. (b) Stimulated emission cross section at 80 K.

