Rare-Earth-Doped Fiber Lasers and Amplifiers

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OPTICAL ENGINEERING

Rare-Earth-Doped Fiber Lasers and Amplifiers

Second Edition, Revised and Expanded

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Since this work, extremely efficient 1.48–μm-pumped Er-doped fiber laser in fact been reported by Wagener et al. at Stanford University [107]. This study estab that a key factor that needs to be optimized to maximize the conversion efficie the erbium concentration. Measurements indicated that fibers with increasingly h concentrations have increasingly high thresholds and low slope efficiencies. The: effects were attributed to the presence of an increasing percentage of Er^{3+} cluster to the fact that clusters dramatically reduce the excited lifetime [133], and there quantum efficiency of the transition. The most efficient fiber laser reported in this used a low-concentration fiber (110 mol ppm Er_2O_3) and a correspondingly lon (42.6 m) [107]. The cleaved fiber ends (~3.5% reflections) formed the laser Fabry- resonator. In spite of the high cavity loss (~29 dB), the threshold was low (~4.8 and the laser was successfully pumped with a low-power laser diode. It emitted si neously in the forward and backward direction, with a forward slope efficiency of [107]. This is the highest slope efficiency and the highest conversion efficiency re in an Er-doped fiber laser (see Table 3). The backward slope efficiency was 31.8 dichroic high reflector was placed at the pump input end, a total slope efficiency of a imately the sum of these two figures, or ~90.4%, would be expected, as well as a su tial reduction in threshold.

This study showed that Er-doped fiber lasers, when pumped near 1.48 μm, at least as efficient as 980-nm pumped lasers. The reasons for this high performanc the low Er concentration and the similarity between the pump and laser photon en [107]. The slope efficiency of 90.4% is, in fact, very close to the quantum limit o predicted for the ratio of pump to signal photon energies. It confirms that the qu efficiency of this transition can be within a few percent of unity. In this light, concen quenching may well explain the suboptimal efficiencies and thresholds reported in Er-doped fiber lasers (see Table 3). It points to the importance of selecting a suffic low rare earth concentration to maximize the performance of fiber lasers or amp This requirement was confirmed in a more recent report of a ring fiber laser that u a very low-concentration fiber (see Table 3) [21]. After optimizing the fiber leng output coupler transmission, the laser had a low threshold (6.5 mW) and a fairl slope efficiency of 38.8%. Tuning from 1525 to 1570 nm was achieved with an intra tunable filter.

3.6.8 Summary

In summary, Er-doped fiber lasers operating close to 1.55 μm are extremely eff When pumped at 1.48 μm, their slope efficiency can be within a few percent of the th cal limit $\lambda_p/\lambda_s \approx 95\%$. Pumping at 980 nm produces a lower, although still subst slope efficiency (theoretical limit of ~63%). Pumping at about 800 nm is unfortu less efficient (~15%) because of pump ESA, even with Yb co-doping. Er-dope lasers are now almost exclusively pumped close to 980 or 1480 nm. They have als operated at multiple wavelengths simultaneously. This feature, of great importan dense WDM systems, is reviewed in Chapter 5.

3.7 YTTERBIUM

3.7.1 Basic Spectroscopy

Ytterbium is one of the most versatile laser ions in a silica-based host. It offers s very attractive features, in particular an unusually broad absorption band that str

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