Tm:YAP & Tm:YAG

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Introduction

Tm doped crystals embrace several attractive features that nominate them as the material of choice for solid-state laser sources with emission wavelength tunable around 2 μm. It was demonstrated that Tm:YAG laser can be tuned from 1.91 up to 2.15 μm. Similarly, Tm:YAP laser has tuning range from 1.85 to 2.03 μm. The quasi-three level system of Tm: doped crystals requires appropriate pumping geometry and good heat extraction from the active media. On the other hand, Tm doped materials benefit from a long fluorescence lifetime, which is attractive for high-energy Q-switched operation. Also, the efficient cross-relaxation with neighbouring Tm ions produces two excitation photons in upper laser level for one absorbed pump photon. This makes the laser very efficient with quantum efficiency approaching two and reduces thermal loading. Tm:YAG and Tm:YAP found their application in medical lasers, radars and atmospheric sensing.

Properties of Tm:YAP depends on crystal orientation. Crystals cut along the “a” or “b” axis (Pbnm space group) are mostly used.

A-cut
Absorption peak 794.8 nm
Absorption cross section 7 x 10^{-21} cm²
Emission wavelength 1980 nm
Emission cross section 5 x 10^{-24} cm²
Excited state lifetime 4.4 ms (6 % Tm)

B-cut
Absorption peak 793.5 nm

Properties of Tm:YAG

Absorption peak 785 nm
Absorption cross section 7.5 x 10^{-20} cm²
Emission wavelength 2013 nm
Emission cross section 2.2 x 10^{-20} cm²
Excited state lifetime 9.2 ms (6 % Tm)

Experimental results

Pumping laser radiation
Fibre coupled diode HL130F400-790 (LIMO)
Emission: 793 nm (Tm:YAP), 785 nm (Tm:YAG)
Fibre: D = 400 μm, NA = 0.22

Focussing optics 1:1
Two achronic doublets, f = 75 mm, spot 380 μm

Laser crystal - AR/AR for pump & laser
Length = 3 mm, Diameter = 3 mm
Tm:YAP: c = 4 at.% Tm, Tm:YAG: c = 6 at.% Tm
Laser resonator
Length = 30 or 40 mm
RM: R = 100 % @ 1.8 - 2.1 μm, T_{max} @ 0.8 μm, flat
OC: R = 92 or 97.5 % @ 1.8 - 2.1 μm, r = 300 mm

Tm:YAP laser, 3 mm, 4%
Pumping wavelength = 793 nm
T_{max} = 30 mm, R_{out} = 92 %, r = 300 mm
Threshold power = 2.8 W
Slope efficiency = 58 %
Maximal output = 4.1 W
Wavelength = 1980 nm

Tm:YAG laser, 3 mm, 6%
Pumping wavelength = 785 nm
T_{max} = 40 mm, R_{out} = 97.5 %, r = 300 mm
Threshold power = 1.1 W
Slope efficiency = 40 %
Maximal output = 3.1 W
Wavelength = 2013 nm

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