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Oscillation behavior of quasi-three-level lasers with residual resonant absorption losses

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Abstract A theoretical model is developed for a quasi-three-level laser with residual resonant absorption losses existing in the unpumped or weakly pumped region of the laser medium, by taking into account the saturation nature of such absorption losses, which is described by a normalized parameter f measuring the feasibility of absorption saturation with respect to the gain saturation. Depending on the magnitude of the parameter f, the quasi-three-level laser will exhibit entirely different oscillation characteristics, distinguishing it from the four-level laser.

Keywords Quasi-three-level laser · Resonant absorption losses · Saturation

1 Introduction

In recent years, with the development of semiconductor lasers that can be used as pump sources, solid-state lasers based on the transitions of trivalent lanthanide rare-earth ions including the ${}^2F_{5/2} \rightarrow {}^2F_{7/2}$ of the Yb ion; the ${}^4I_{13/2} \rightarrow {}^4I_{15/2}$ of the Er ion; the ${}^5I_7 \rightarrow {}^5I_8$ of the Ho ion; and the ${}^3F_4 \rightarrow {}^3H_6$ of the Tm ion, have attracted more and more attentions of researchers. Differing from the traditional four-level Nd ion lasers operating on the ${}^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition ($\sim$1μm of emission wavelength), these rare-earth ion lasers belong to the category of quasi-three-level lasers, for which the lower laser level is located above the ground level or the lowest level of the manifold terminating the laser transition, by an energy spacing usually less than $\sim$1,000 cm^{-1}. As a result, a quasi-three-level laser operating at room-temperature has, in general, an amount of intrinsic resonant absorption losses, arising from thermal excitation of the lower laser level. Due to the presence of such inherent resonant absorption losses, quasi-three-level lasers are expected to be different from their four-level counterparts in basic oscillation characteristics.

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