mode locking method

There are many ways to generate ultrafast laser operations. One can use real saturable absorbers, such as semiconductor saturable absorber mirror (SEASM) [SESAM mode-locked red praseodymium laser] or low-dimensional material-based saturable absorbers such as graphene [] and blablabla [], and solid-state laser media []. One can also exploit artificial saturable absorbers. The two most prominent artificial saturable absorber mode locking techniques are called Kerr-Lens Mode Locking (KLM) [1][2][3][4][5][6][7] early[8][9][10] and Additive Pulse Mode Locking (APM) [].

Pr:YLF

By virtue of its vast variety of robust emission lines ranging from visible to near infrared spectral range, trivalent praseodymium (Pr3+) ions have been identified as one of the most potential candidates for efficient visible lasers.

In recent years, with the development of blue laser diodes (LDs), which are both compact and easily available, diode-pumped all solid-state Pr3+-doped material visible lasers are gradually attracting more and more attention.

CW

In the field of continuous-wave (cw) visible laser operations, enormous progresses have been achieved with Pr3+-doped materials, such as LiYF4 waveguide [Red and orange Pr3+:LiYF4 planar waveguide laser, Green, orange, and red Pr3+∶YLiF4 epitaxial waveguide lasers], ZBLAN fiber [Blue Pr3+-doped ZBLAN fiber upconversion laser, Visible–NIR tunable Pr3+-doped fiber laser pumped by a GaN laser diode], waterproof fluoroaluminate glass fiber [High-power direct green laser oscillation of 598 mW in Pr3+-doped waterproof fluoroaluminate glass fiber excited by two-polarization-combined GaN laser diodes] or LiLuF4 monocrystalline fiber [Visible laser operation in a Pr3+:LiLuF4 monocrystalline fiber grown by the micro-pulling-down method] and crystals such as LiYF4 [Diode pumping of a continuous-wave Pr3+-doped LiYF4 laser], LiLuF4 [Visible laser emission of solid state pumped LiLuF4:Pr3+], LaF3 [Diode pumped laser operation and spectroscopy of Pr3+:LaF3] and KY3F10[Wide wavelength tunability and green laser operation of diode-pumped Pr3+:KY3F10]. Lately, cw watt-level high power Pr:YLF visible lasers pumped by intra-cavity frequency-doubled Optically Pumped InGaAs Semiconductor Laser (2ω-OPSL) [High-power red, orange, and green Pr3+:LiYF4 lasers] or LD [Power scaling of blue-diode-pumped Pr:YLF lasers at 523.0, 604.1, 606.9, 639.4, 697.8 and 720.9nm] have been realized with high efficiencies.

Q switching

In pulse laser experiments, LD-pumped Q-switched Pr3+ ion visible lasers with kilohertz repetition rates and nanosecond pulse widths have been reported [2013 Cr4+-Doped Y3Al5O12 as a Saturable Absorber for a Q-Switched and Mode-Locked 639-nm Pr3+-Doped LiYF4 Laser, 2014 InGaN diode pumped actively Q-switched intracavity frequency doubling Pr:LiYF4 261 nm laser].

Regarding the pulsed oscillation of Pr3+ lasers, passive Q-switching was reported with a semiconductor saturable absorber mirror (SESAM) [2011 Passively Q-switched Pr:YLF laser],

[2012 Wavelength Tunable Q-switch Laser in Visible Region with Pr3+-doped Fluoride-glass Fiber Pumped by GaN Diode Lasers] We report passively Q-switched operation of a diode-pumped Pr:YLF laser using an AlInGaP on GaAs SEmiconductor Saturable Absorber Mirror. Q-switched pulses with 145ns duration and 23mW average output power at 639.5nm are obtained.

Cr4:YAG crystal [10,11], gold nanoparticles [12], and nanosheets of transition metal dichalcogenides (TMDs) [13,14] as saturable absorbers.

mode locking

As for mode locking operations, The first mode-locked Pr3+:YLiF4 visible lasers at 607 and 640 nm utilizing the Kerr-lensing effect and initiated by saturable absorbers were realized in 1995 by introducing argon-ion lasers as the pump source. [Kerr-lens mode-locked visible transitions of a Pr:YLF laser]. The first self-staring Kerr-lens mode locked laser at 607 nm with pulses width of 15 ps was reported in 1996, which was also pumped by an argon-ion laser [Self-starting Kerr-lens mode-locked femtosecond Cr4+:YAG and picosecond Pr3+:YLF solid-state lasers]. In 2014, pumped by an 2ω-OPSL, the first semiconductor saturable absorber mirror (SESAM) mode-locked praseodymium solid-state laser at 640 nm was obtained by Gaponenko et al, with pulses duration of ∼18 ps. [SESAM mode-locked red praseodymium laser]. Due to the narrow gain bandwidth of the transition (3P0→3F2) in the Pr3+:YLF, generating mode-locked sub-picosecond pulses is challenging. The maximum averaged output power reached 16 mW at an incident pump power of 3.75 W.

In the past one year, the wavelength of self-mode-locked visible pulsed lasers extent to the spectral range of green and deep red for the first time [Laser-diode pumped self-mode-locked praseodymium visible lasers with multi-gigahertz repetition rate]. The system was pumped by laser-diode and the repetition rates were multi-gigahertz (GHz). The maximum output power reached 612 mW with the slope efficiency of 46.9% at 639 nm. Following closely, still by introducing a SESAM, but pumped by InGaN laser-diode, which is different from Gaponenko et al, mode-locking operation at the wavelength of 640 nm was attained. [Pr3+:YLF mode-locked laser at 640 nm directly pumped by InGaN-diode lasers]. a maximum averaged output power of 65 mW was obtained at absorbed pump power of 3.8 W, with a pulse width of 45 ps (FWHM) at a pulse repetition rate of 108 MHz.

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