Cascaded Kerr-lens partial mode-locking and optimally-coupled cw single-frequency operation of a Nd:YLF/ppKTP ring laser

J.-J. Zondy[1,*], F. A. Camargo[2], T. Zanon-Willette[1], V. Petrov[3], and N. U. Wetter[2]
[1]Laboratoire Commun de Métrologie LNE-CNAM, 61 rue du Landy, F-93210 La Plaine Saint-Denis, France.
[2]Instituto de Pesquisas Energéticas e Nucleares (CNEN-IPEN/SP), CEP 005508-000 São Paulo, Brazil
[3]Max-Bom-Institute for Nonlinear Optics and Ultrafast Spectroscopy, 2A Max-Bom-Str., D-12489 Berlin, Germany
**Corresponding author e-mail : jean-jacques.zondy@cnam.fr; Ph : +33 (0)6 7276 5383; Fax: +33 (0)5880 8900*

Cascaded second-order nonlinearities are often used for picosecond passive mode-locking of diode-pumped Nd-doped solid-state lasers via *nonlinear mirro*r mode-locking (NLM) [1] or *cascaded-second-order* mode-locking (CSM) [2]. Both techniques require standing-wave resonators, where the forwardly generated second-harmonic (SH) wave and/or the fundamental wave (FH) pass more than once through the nonlinear crystal, with a proper phase shift of the back-reflected SH. In this work [3], a self-starting partial mode-locking dynamics triggered by *pure* cascaded KLM processes arising from an intracavity temperature phase-mismatched ppKTP is demonstrated for the first time in a unidirectional Nd:YLF ring resonator operating on the broad 1321nm transition. In contrast with KLM lasers operating near one of the stability limit of the resonator to enhance the nonlinear gain modulation, our unidirectional intracavity frequency-doubled cw ring laser (ICSHG laser) – originally designed to demonstrate the concept of *optimal ICSHG coupling* [4,5] – operates at the middle of the resonator stability range with a large laser-crystal to nonlinear-crystal waist ratio w/w_0=317µm/47µm~6.5. When the ppKTP crystal is inserted into the cavity with its temperature substantially phase-mismatched from the gain-center wavelength (1321nm), a strong periodically pulsing dynamics at the cavity free-spectral range repetition rate (f_{rep}=421MHz) is systematically observed, whichever the sign of the cascaded Kerr nonlinearity (focusing with $\Delta k<0$ or defocusing with $\Delta k>0$ [6]) – in contrast with CSM lasers. The output of the ICSHG laser consists then of a train of pulses superimposed on a phase-incoherent DC signal background (Fig.1b), and the fundamental or harmonic spectra exhibit a strong spectral gain broadening (Fig.1c) as compared with the narrow-line cw spectrum prior to the ppKTP insertion. This partial KLM regime disappear below a diode pump threshold P_{abs}~6.5W. The transition from partial KLM to genuinely cw SLM regime could be achieved only with the insertion of a suitable intracavity thin etalon quenching the cascaded second-order nonlinear processes. While under partial KLM regime the maximum average broadband red power (660.5nm) did not exceed $P_{2\omega}$ ~0.15W at $\Delta kL\sim\pm3\pi$ and P_{abs}=13W of diode pumping, under cw SLM operation a record $P_{2\omega}$=1.4W in red SLM emission corresponding to ~100% conversion of the 1321nm SLM maximum output power available from the laser (P_{ω}=1.4W using an optimal T=2% out-coupling mirror) was obtained (Fig.1a), satisfying thus the criterion of *optimal* ICSHG coupling as theoretically predicted in the late 60's [3-4,5].

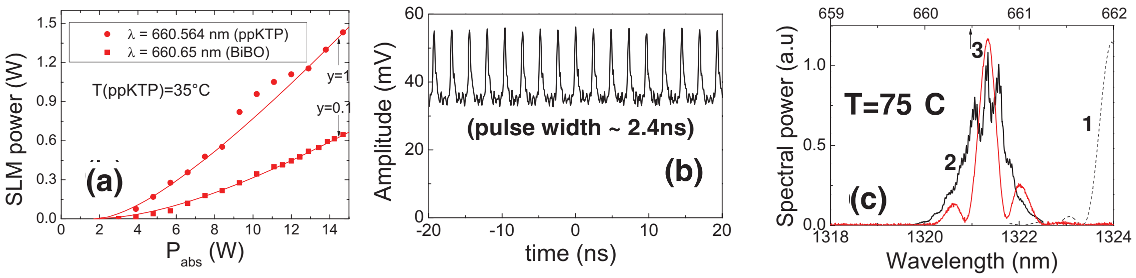

Fig. 1. (a) Red cw SLM output power (660.5nm) in presence of a partially-coated thin etalon; (b) typical fundamental laser time traces when the ppKTTP is inserted with $\Delta k(T)\neq0$ and (c) corresponding fundamental (line 2) and harmonic (line 3) spectra. The thin dashed curves (1) refer to the position of the narrow ($\Delta\lambda_{NL}$=0.8nm) $\mathrm{sinc}^2(\Delta k l_c/2)$ QPM spectral acceptance curve of ppKTP..

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