

INSTITUT NEEL

Quantum internship – Academic year 2025-2026

Title : Investigation of PbWO₄ as a potential crystal for triple photons generation

Level : Master 1

General Scope:

Triple photon generation (TPG) is a nonlinear interaction consisting in the scission of a high energy pump photon $\hbar\omega_p$ into three lower energy photons ($\hbar\omega_1, \hbar\omega_2, \hbar\omega_3$). These three down-converted photons provide a new exotic quantum state of light that exhibits statistics going beyond the usual Gaussian statistics associated with coherent sources and optical parametric twin-photon generators. The previous demonstrations of TPG have been achieved in a KTP crystals using a stimulation over two modes of the triple state [Douady J. and Boulanger B. – *Experimental demonstration of a pure third-order optical parametric downconversion process – Optics Letters, 2004, 29(23), 2794-2796*] or over one mode [Bertrand J., Boutou V., Felix C., Jegouso D., and Boulanger B. - *Experimental demonstration and modeling of near-infrared nonlinear third-order triple-photon generation stimulated over one mode - Applied Physics Letters Quantum, 2025, <https://doi.org/10.1063/5.0254046>*]. Performing TPG without any stimulation, which corresponds to a third-order spontaneous down-conversion process, will require a crystal of higher nonlinearity than KTP. We have targeted PbWO₄ that has also the advantage compared with KTP to be an acentric crystal, which prevent any parasitic second-order process that could lead to a triple state.

Research topic and facilities available:

The internship will be devoted to a preliminary step of TPG that will consist in the investigation of third harmonic generation (THG) in PbWO₄. THG ($\omega + \omega + \omega \rightarrow 3\omega$) is the reverse process of a degenerate TPG ($3\omega \rightarrow \omega + \omega + \omega$). The momentum conservation of THG is the same than that of TPG, i.e. $\hbar 3\omega = \hbar\omega + \hbar\omega + \hbar\omega$, while the conversion efficiency of THG is much higher than that of TPG by several order of magnitude. It is then more convenient to start with the study of THG in order to access to the birefringent phase-matching (BPM) properties of PbWO₄, including the BPM directions and the associated angle and wavelength acceptances.

The sphere method will be used in order to measure the BPM directions of PbWO₄. A sphere of the crystal will be shaped at Institut Néel with a diameter $D \approx 8$ mm and an acylindricity accuracy $\Delta D/D$ of about 1%. It will be polished to optical quality and stuck on the top of a Euler circle that allows the sphere to rotate on it-self. The sphere will be stuck oriented along an axis that has to be defined with an accuracy of $\pm 0.5^\circ$ using polychromatic X-rays diffraction in backscattered Laue geometry. The incoming beam at ω will be emitted by a Light Conversion optical parametric source of 15 ps pulse width (FWHM) and 10 Hz repetition rate, tunable between 0.4 μm and 12 μm . The BPM angles, θ_{PM} , will be read directly on the Euler circle with an accuracy of $\pm 0.5^\circ$: it corresponds to a maximum value of the THG conversion efficiency. A Hamamatsu amplified photodiode S2281-01 will be used to record the generated energy at 3ω . The incident energies were measured with an OPHIR PE10 Joulemeter.

Required skills: electromagnetism, optics, laser physics

Starting date and duration: 18 May 2026 – 20 July 2026

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