Metrology for quantum physics (4 ECTS)

• Signal and noise (2 ECTS)

Teachers: *lecture: Pierre Cladé (LKB, ENS, SU), TD: Mathieu Manceau (LPL, Sorbonne Paris, Nord), TP: Bérengère Argence (LKB, SU)*

Master the physical and statistical analysis of signals and noises. Know the main fundamental noises and methods for improving the signal-to-noise ratio. Analyze, interpret and present measurement results.

- **Statistics**
    - continuous and discrete random variables
    - some usual laws
    - estimators
    - likelihood
    - Monte-Carlo method
    - adjustment, multi-dimensional random variables, sensitivity
- **Caracterization of noise**
    - discrete-time random process: Allan variable
    - continuous-time random process: notion of ergodicity - correlation - power spectral density, the main fundamental noises, methods for improving the signal-to-noise ratio
- **Pratical work (3 times 4h)**
    - **Spectral analysis** : operate a spectrum analyzer, determine the bandwidth of a filter and measure the spectral noise density of a light-illuminated photodiode.
    - **Phase noise in an optical fiber** : transport of a stable optical frequency in a single-mode optical fiber, extraction of phase noise from the frequency beat signal between a reference laser beam and another laser beam reflected in a 20 m optical fiber. The two laser beams originate from a laser diode and are frequency-shifted by double-pass through an optical-acoustic modulator. Study and control of phase noise.
    - **Candling effect detection:** Measurement of the deflection of a laser beam induced by an index gradient. This gradient results from a local variation in temperature. Measured using synchronous detection, it can be used to determine the thermal diffusion length of oil and the profile of a surface.

- **Ultrastable Lasers (2 ECTS)**

***Teachers** : lecture : Thomas Zanon (MONARIS, SU), TP : Thomas Zanon, Benoit Darquié (Laboratoire Physique des Lasers, Sorbonne Paris Nord)*

- Notion of phase noise/frequency noise
- Phase noise and linewidth
- Experimental techniques for linewidth control
- Femtosecond comb frequency measurements

TP (2 times 4 hours) : Realization of an optical clock