# EUROPHOTONICS-POESII MASTER COURSE

## PROPOSAL FOR A MASTER THESIS

**Dates: April 1st, 2016 – September 30th, 2016**

**Laboratory : ICFO**
**City, Country : Castelldefels (Barcelona), Spain**

**Title of the master thesis : Approximate t-designs in bosonic systems**

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**Summary of the subject (maximum 1 page) :**

Recently there has been a lot of interest in the so-called quantum t-designs. A Quantum t-design on a given Hilbert space is a (usually finite) subset of the unitary group that mimics properties of the uniform distribution on this group (Haar measure). To be more specific, with the help of a t-design one can effectively compute averages of arbitrary polynomial of degree t on this group. Quantum designs find applications in different fields of quantum information such as quantum tomography, quantum cryptography, compressed sensing, quantum metrology, and foundations of statistical mechanics.

Despite their usefulness, quantum t-designs are in general not well-understood and efficient constructions for them are only known for t smaller than four (they are based on the properties of the so-called Clifford group). For this reason the approximate t-designs were introduced. These are, as the name suggests, objects that are t-designs approximately, i.e. they satisfy the desired properties with some accuracy. It was recently proven that one can generate approximate designs using random circuits formed from the set of the generating gates in a given Hilbert space. The generating set of gates is a (usually finite) set consisting of gates with the help of which one can approximate any unitary operation with arbitrary accuracy.

The objective of this project is to study approximate t-designs in the context of bosonic systems, having in mind especially Hilbert spaces implemented by quantum optics. The focus of the project will be to generate random quantum circuits in the systems of N bosons in D modes and checking numerically how well these circuits approximate the uniform distribution on the corresponding unitary group. Specifically, the main stages of the project will be:

1. Writing of a numerical procedure for generation of random bosonic circuits for a

specific choice of the generating set of gates. The numerics will be carried out for values of N and D accessible numerically.

2. Analysis of how fast the random bosonic circuit approximate t-design (for different choices of the generating sets of gates, with the emphasis on the dependence on the number of particles N and number of modes D)
3. Implementation of random bosonic circuits to generate families of bosonic states useful for quantum metrology.

The above proposal is related the recent joint work of scientist from ICFO and UCL London.

**Keywords : linear quantum optics, t-designs, universal sets of gates for bosonic systems, quantum computing, monte-carlo methods**

**Additional information :**

* Required skills : knowledge of Mathematica and/or Matlab, basic group theory, familiarity with bosonic (passive) linear optics
* Miscellaneous :