Candela: Towards quantum-based photon standards

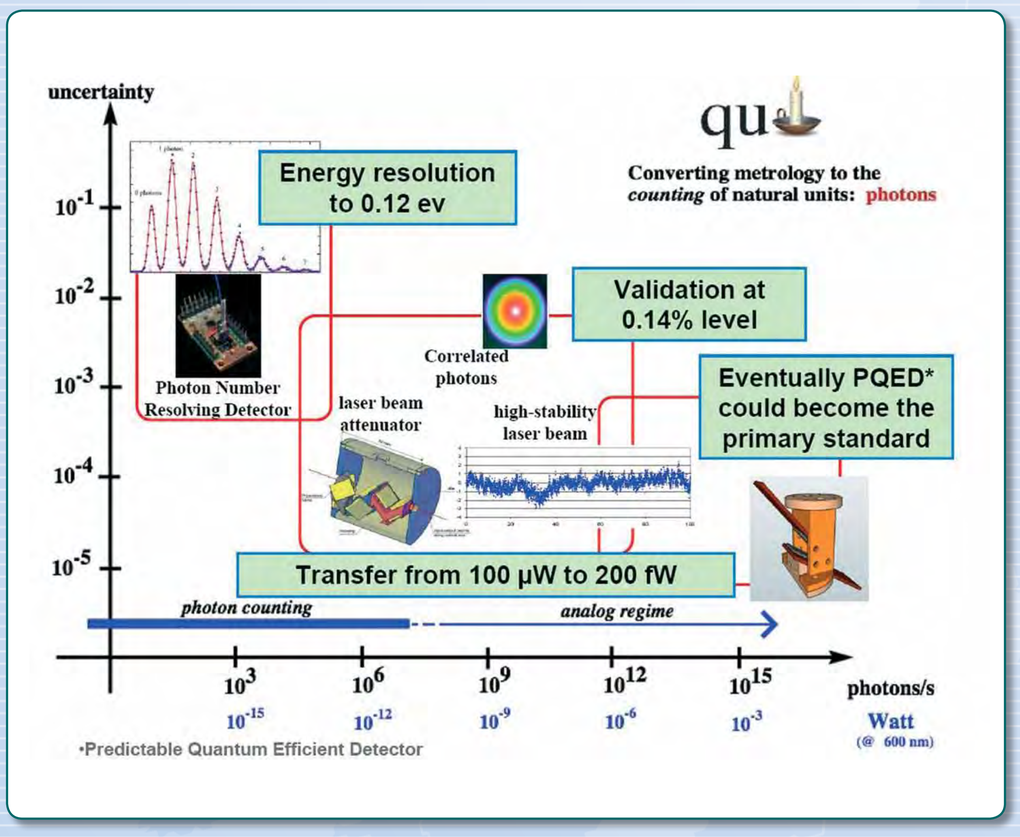
EURAMET
European Association of National Metrology Institutes

The need for the project

The candela is the SI base unit of luminous intensity, however, its definition is not linked to the concepts of modern physics that underpin the development of quantum optical technologies.

A change in optical metrology is therefore required, in order to bridge the energy difference between emerging quantum technologies and classical radiometry and photometry, and connect the measurement of macroscopic quantities like optical power with the quantum world of photon number measurement.

This project aimed to develop standards for photon metrology from the signal level (10^{13} - 10^{14} photons/s) of existing radiometric standards (10-100 microwatts) down to single photons. It also aimed to address requirements for new SI traceable quantum based photon standards (in units of photons/second) and the challenge of expressing the candela in terms of photons per second.

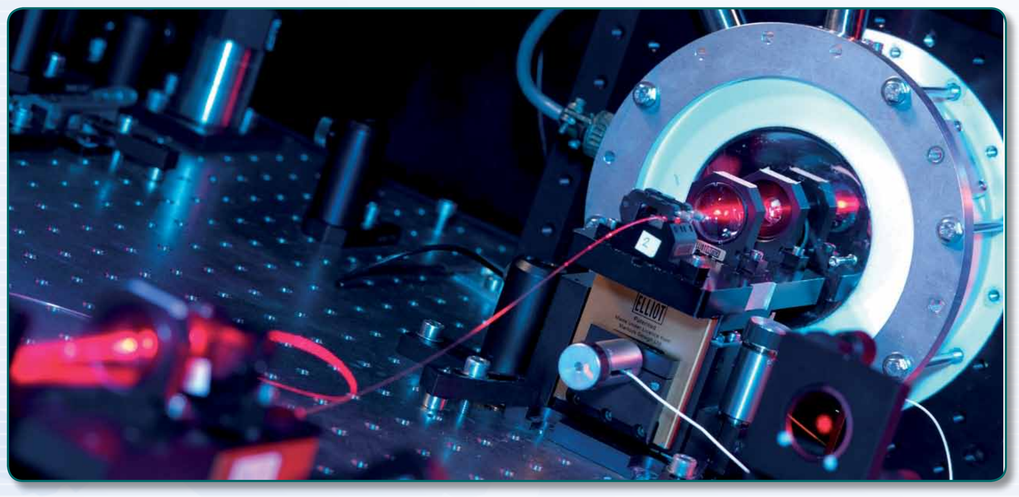


Schematic representation of the linkage of the few photon regime to the SI.

Technical achievements

The project developed silicon photodetectors with a quantum efficiency predictable with an uncertainty below 10 ppm over the whole visible range of wavelengths and suitable for the measurement of photopic fluxes. It also produced transition-edge detectors able to resolve up to 12 photons with an energy resolution better than 0.12 eV for the measurement of single photon fluxes. Techniques for scaling between low and high photon flux regimes, with uncertainties in the calibration chain of approximately 100 ppm were also developed.

These techniques were validated through the Planck constant; by the ratio between the photon flux and the radiant flux of a monochromatic beam at wavelengths 488 nm, 576 nm and 761 nm at 100 µW and 761 nm at 1 pW.



Confocal microscope system developed to pump and collect single photons.

New primary standards

Developed new primary standards for the photometry community and a traceability chain based on the most widely used detectors - silicon photodiodes. These new standards are portable, cheaper and easier to use than current standards, making them more accessible to end-users (e.g. National Metrology Institutes and LED manufacturers).

Commercialisation of PQED devices

The project developed Predictable Quantum Efficient Detectors (PQED) which have been made commercially available by Fitecom Ltd, a Finnish service provider of measuring equipment.

Standards for photon counters

Provided validated and traceable standards for the manufacturers of photon counting devices. Specifically, the project carried out spatial uniformity measurements by characterising photon counters. Results showed that candidate channel photomultipliers and single photon counting modules showed poor uniformity results. Publication of this work led to Princeton Lightwave setting up their own spatial uniformity characterisation facility to improve the performance of their diodes.

Redefining the candela

Demonstrated the validity of expressing the candela in terms of a countable number of photons per second.

Joint Research Project (JRP) Short Name: qu-Candela • JRP-Coordinator: Maria Luisa Rastello (INRIM) • JRP-Partners: CMI (Czech Republic), INRIM (Italy), JV (Norway), Metrosert (Estonia), MIKES (Finland), NPL (UK), PTB (Germany)

The research within this EURAMET joint research project received funding from the European Community's Seventh Framework Programme, ERA-NET Plus, under the iMERA-Plus Project - Grant Agreement No. 217257

EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union