



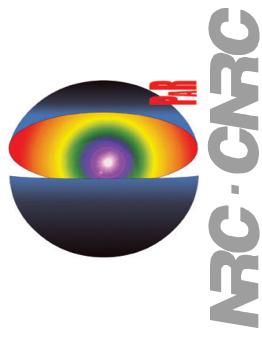
A new quantum candela metrology facility at NRC

Charles Bamber
Institute for National Measurement Standards
National Research Council Canada



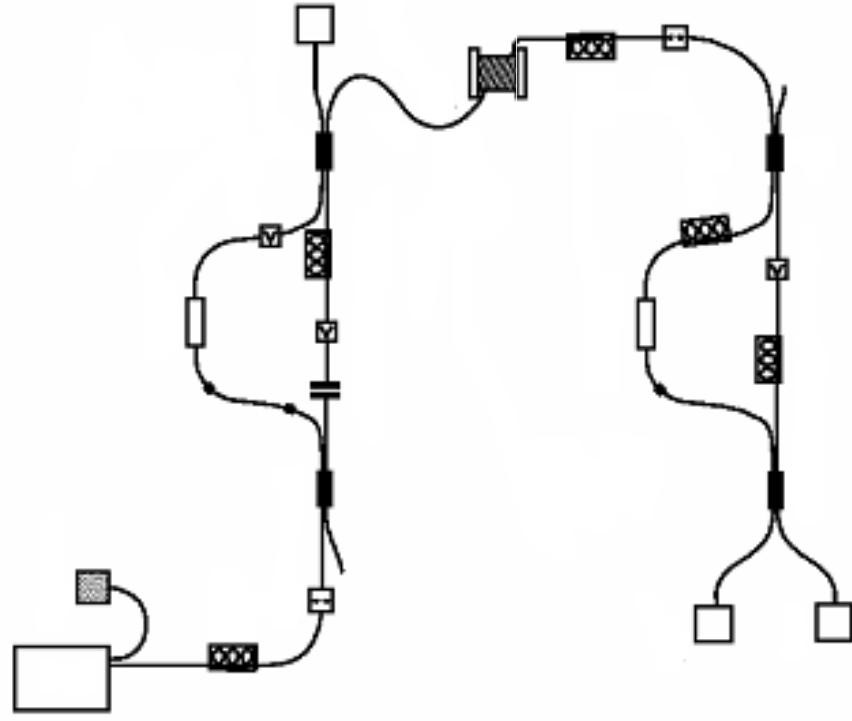
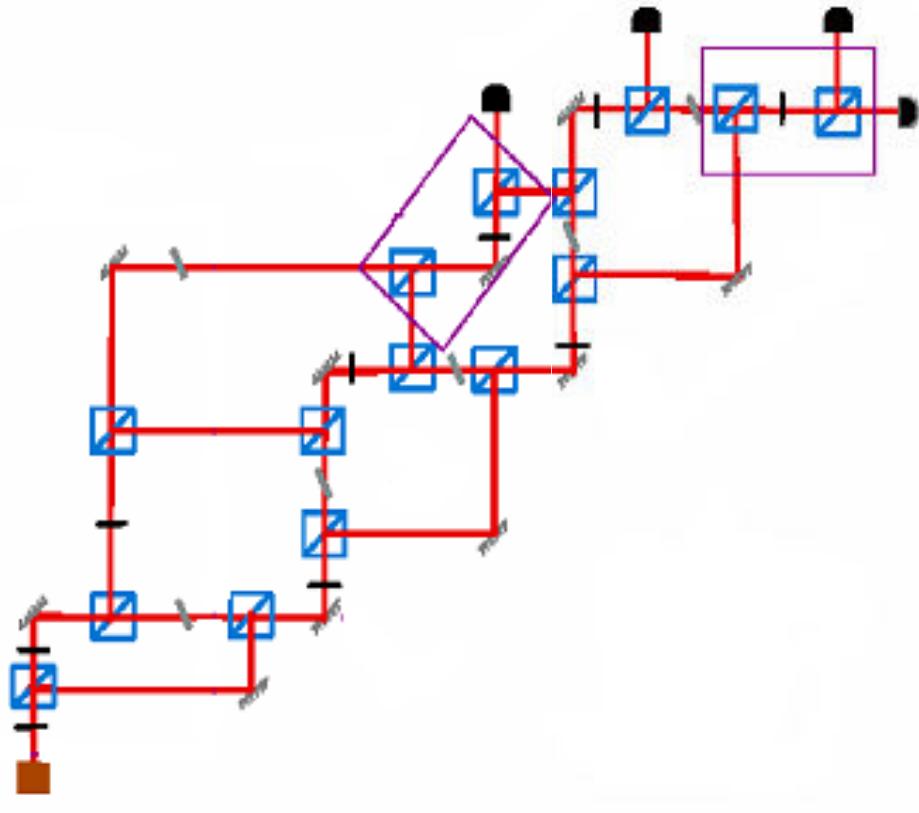
Outline

- Photon-on-demand sources based on quantum dots
- Single photon detectors based on superconducting nanowires
- Quantum candela realized by either photon-on-demand sources or single photon detectors





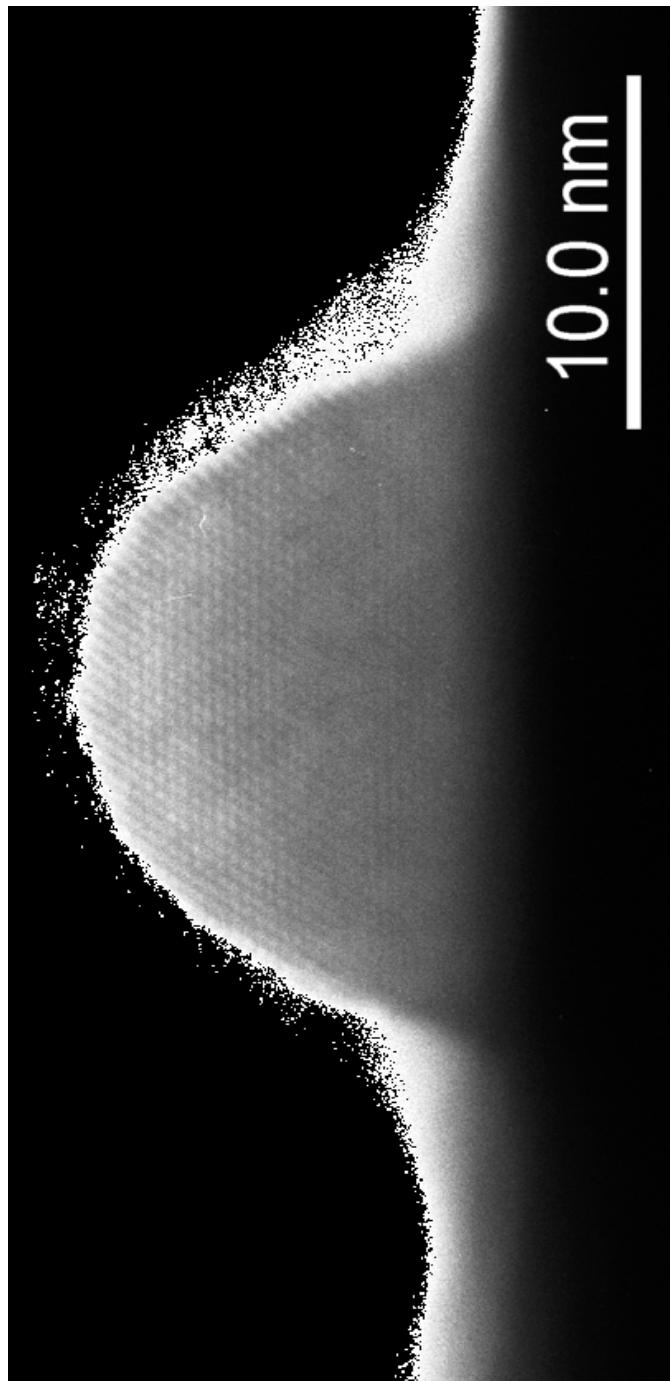
Photon-on-demand sources are needed for Quantum Computing and Quantum Key Distribution





Institute for National Measurement Standards
Institut des étalons nationaux de mesure

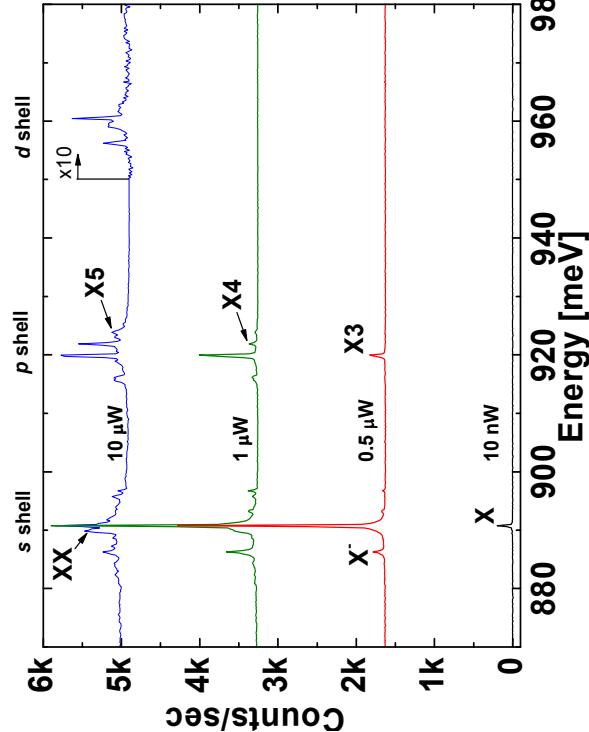
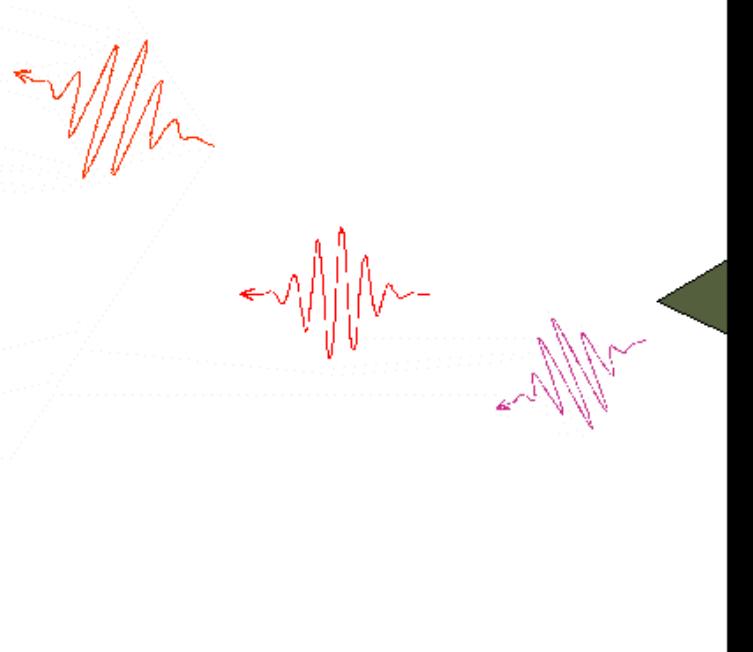
NRC-Institute for Microstructural Studies is developing sources of single and entangled photons





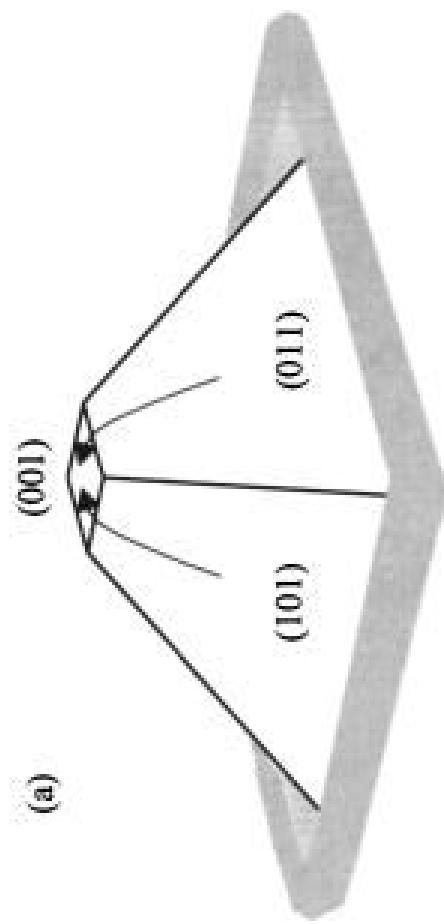
Bare quantum dots behave like single atoms

Each time they're excited
they generally emit one
photon at a time with $\Delta\lambda$
into $\Delta\phi$

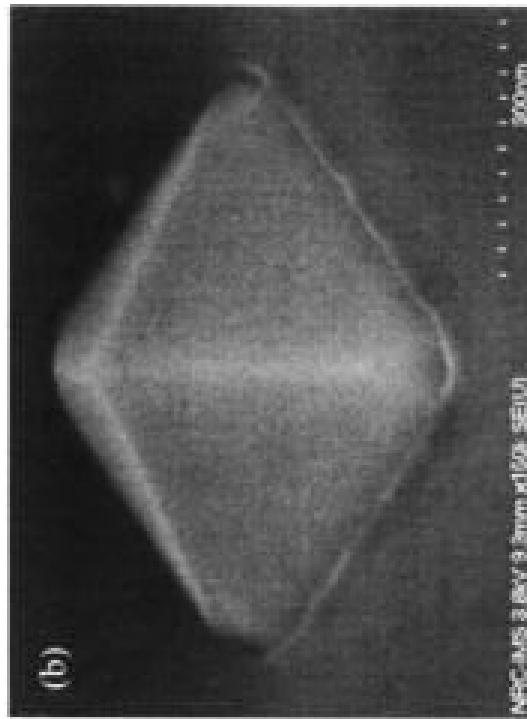




NRC-IMS fabricate quantum dots by engineering nucleation sites

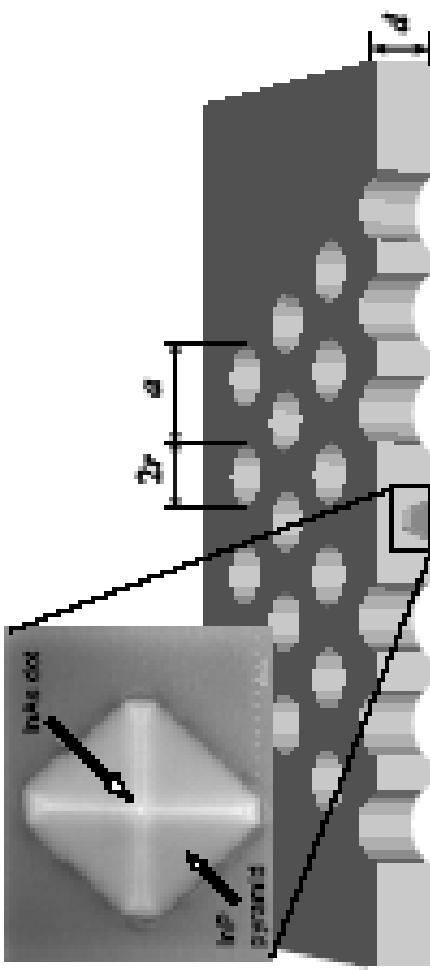


This provides control over the position of the quantum dot

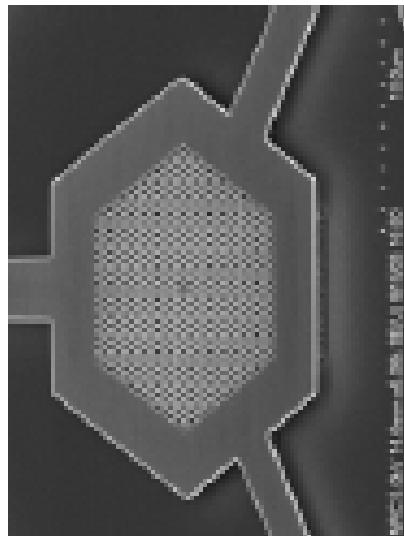




Coupling to a cavity changes the emission characteristics



A photonic crystal cavity can be tuned to the QD emission by varying r and a



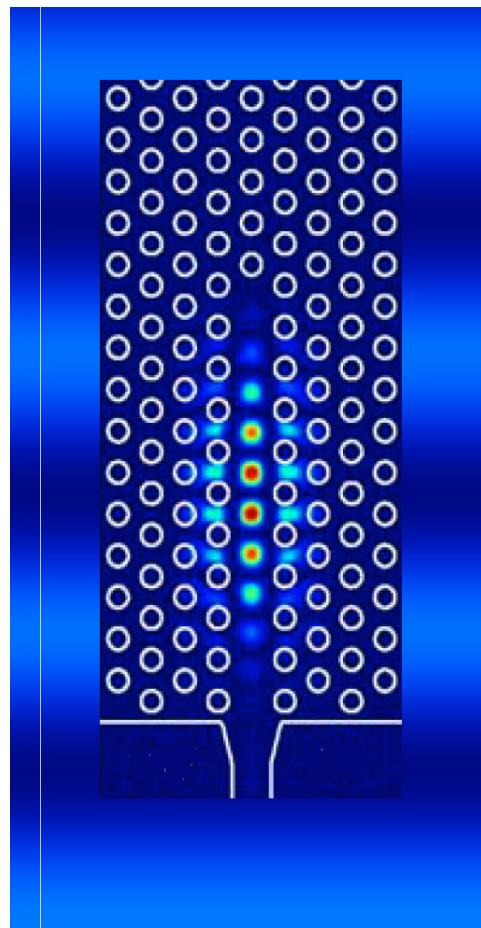
Opt. Express, 15, 1267 (2007)

J. Vac. Sci. Technol. A 24, 791, (2006)



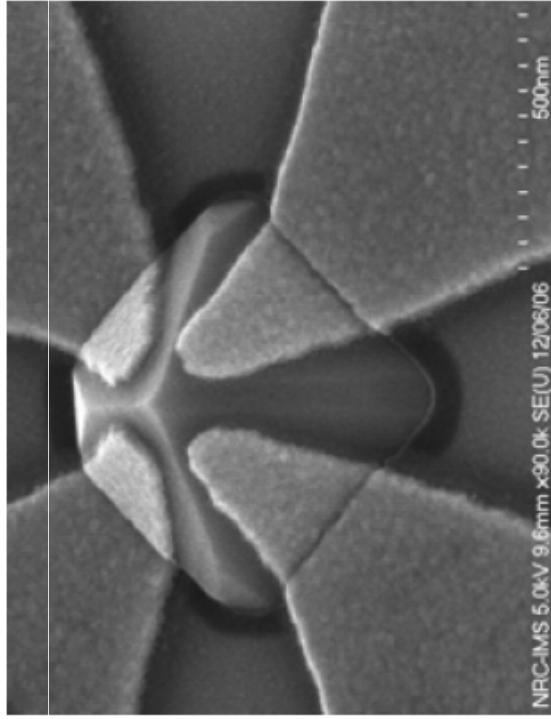


Applied fields can tickle the QDs for deterministic emission of single photons



Surface Acoustic waves

Phys. Rev. Lett. **99**, 193901 (2007)

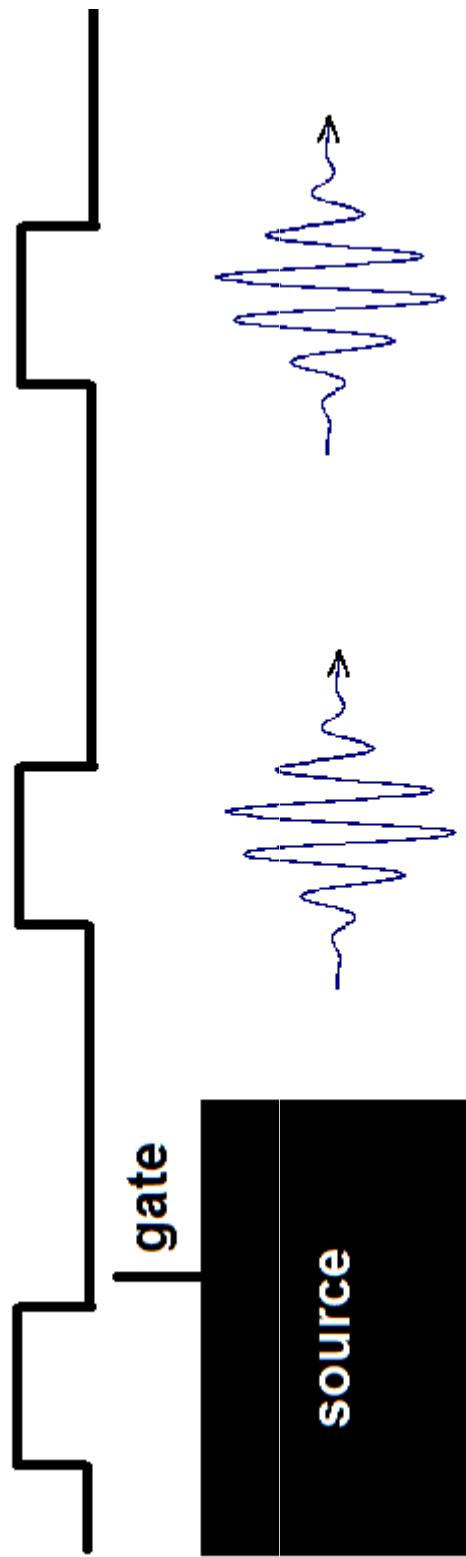


Electrostatic gating

Phys. Rev. B **78**, 195301 (2008)

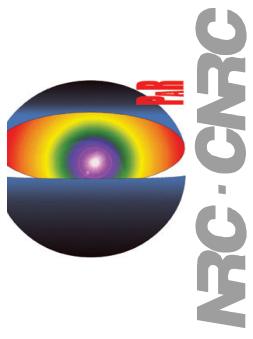
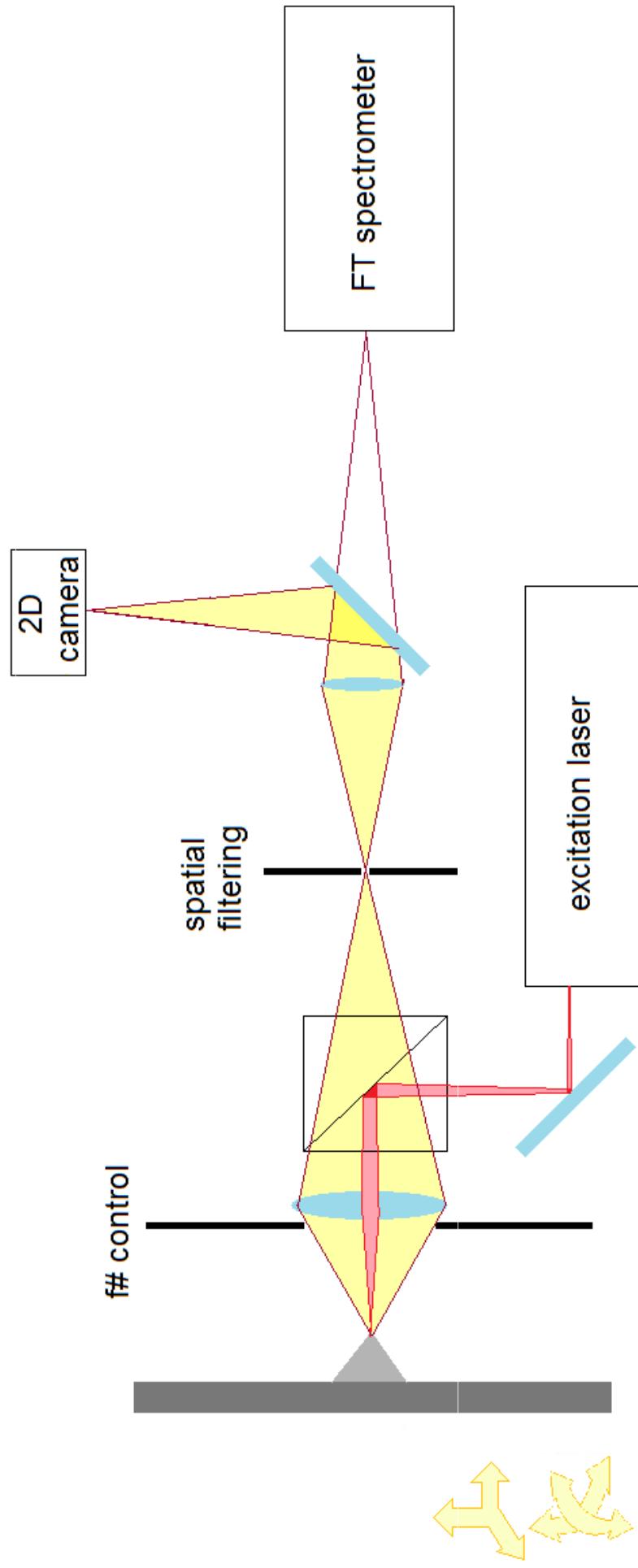


Goal is to combine these technologies to fabricate a practical manufacturable photon-on-demand source



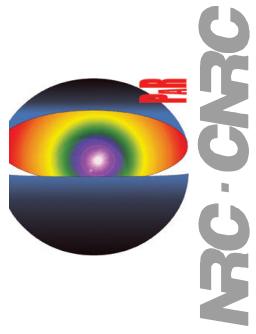
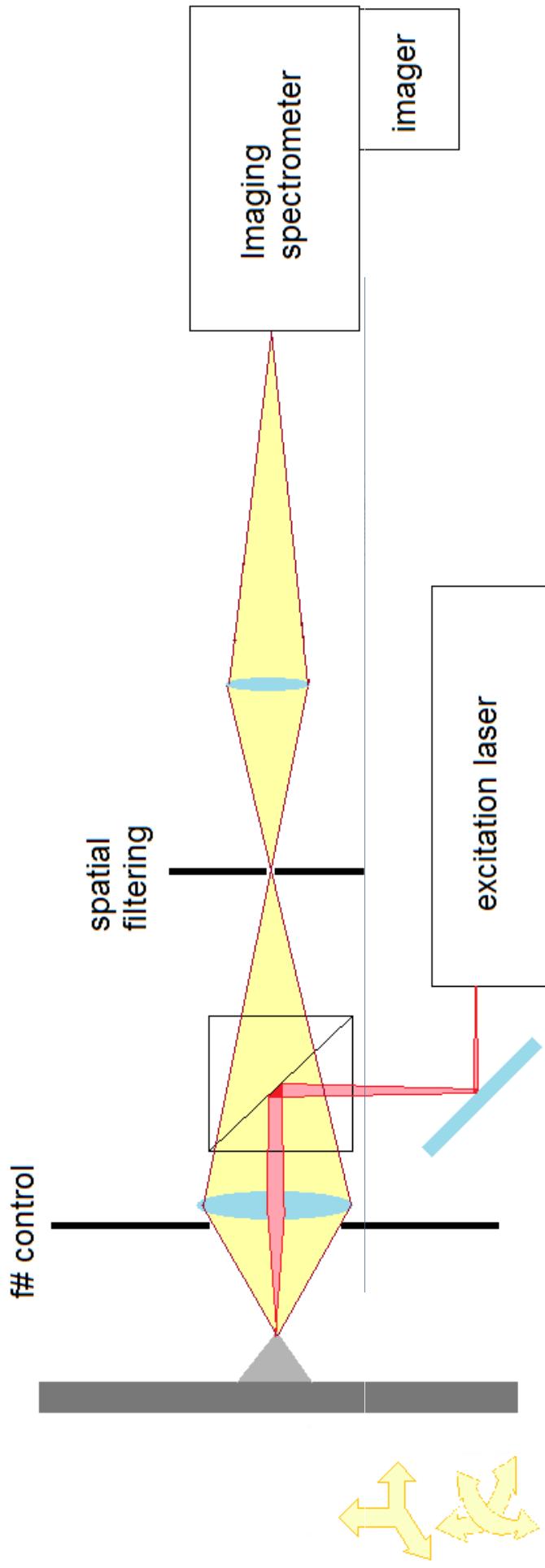


NRC-INMS is developing infrastructure for characterizing these sources



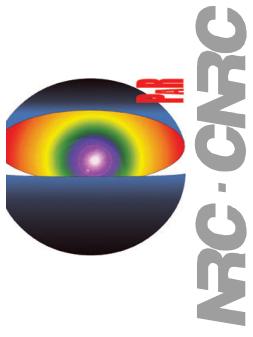
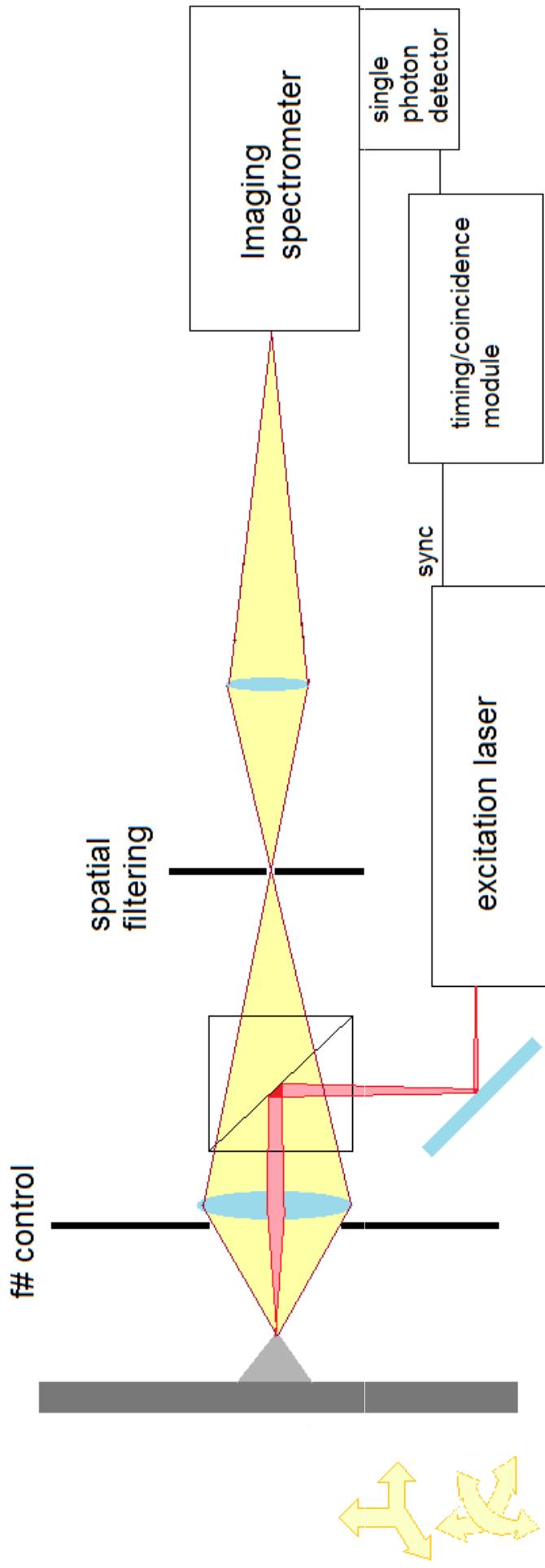


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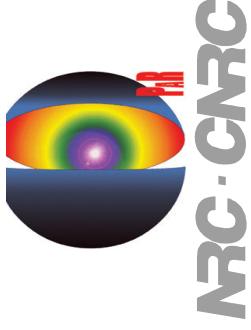
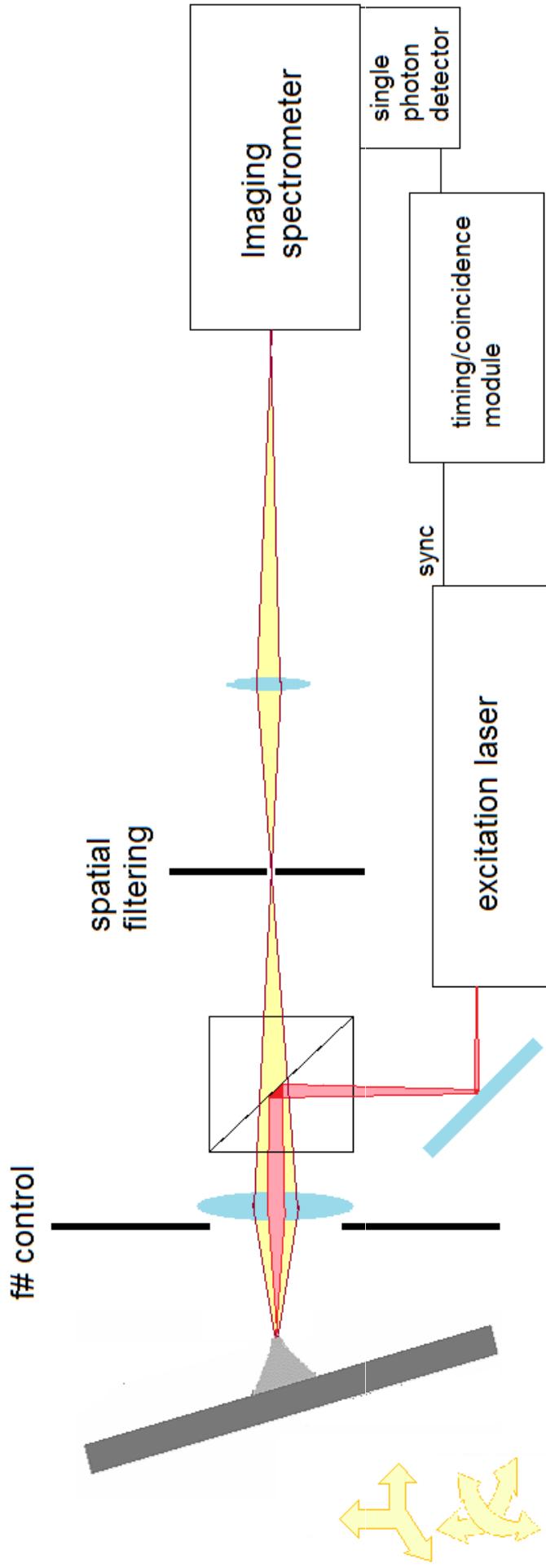


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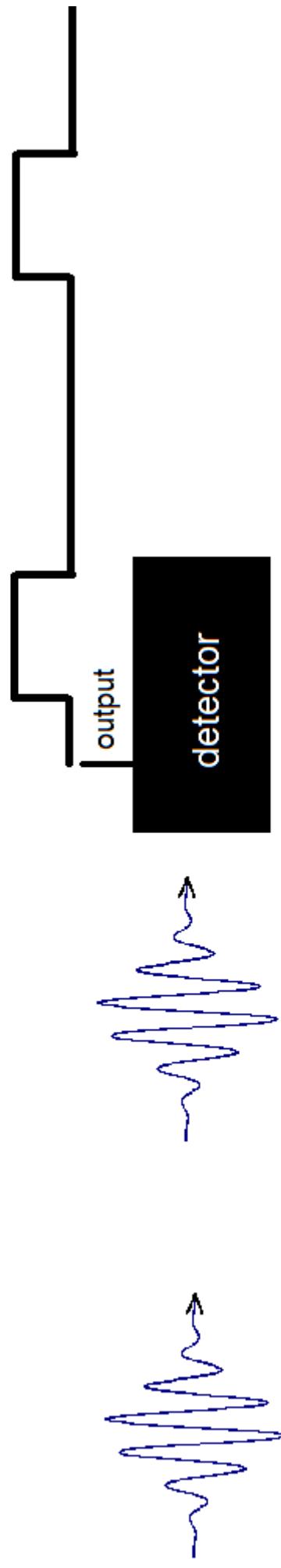


The emission mode of the system can be fully mapped out





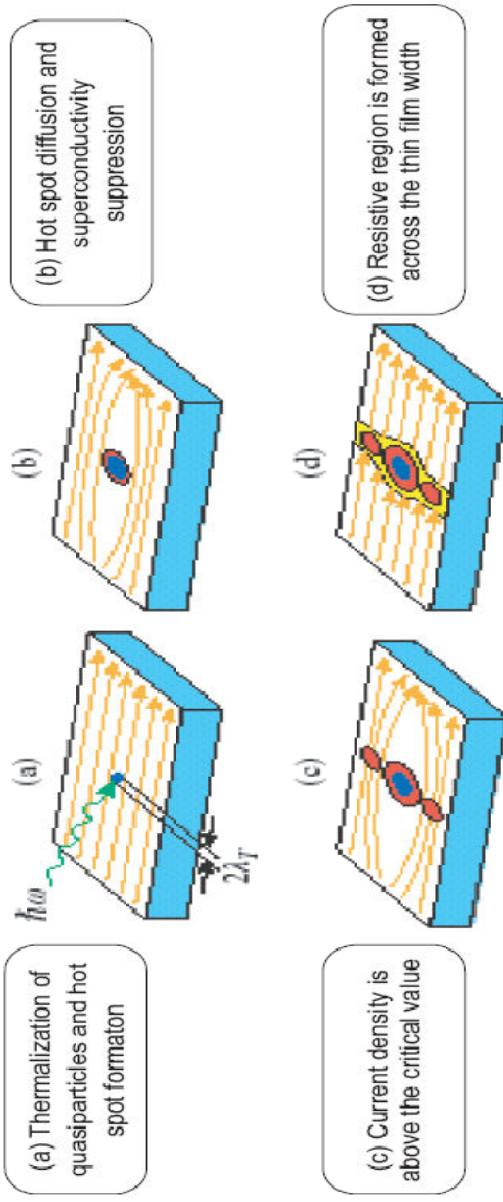
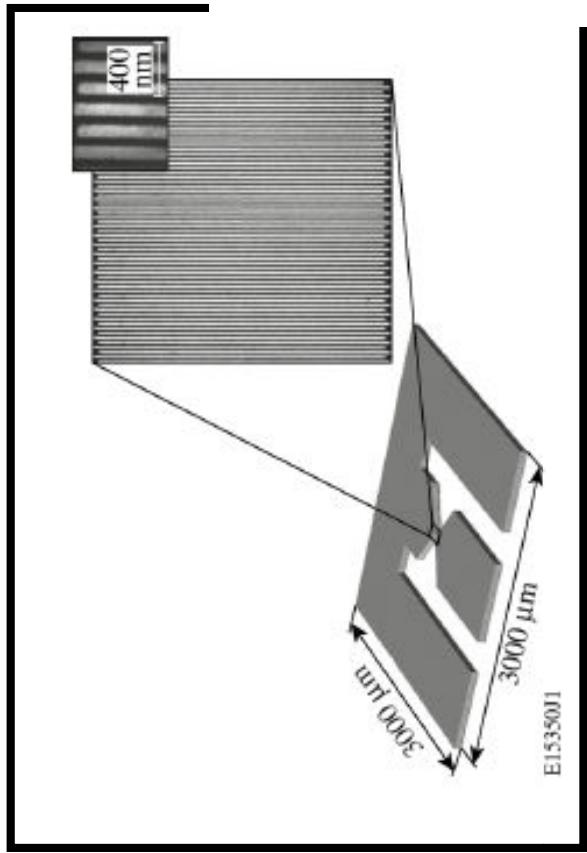
The other necessary technology under development is the single photon detector



- Imperfect quantum efficiency (as a function of wavelength), dark counts, afterpulsing and timing jitter need to be characterized

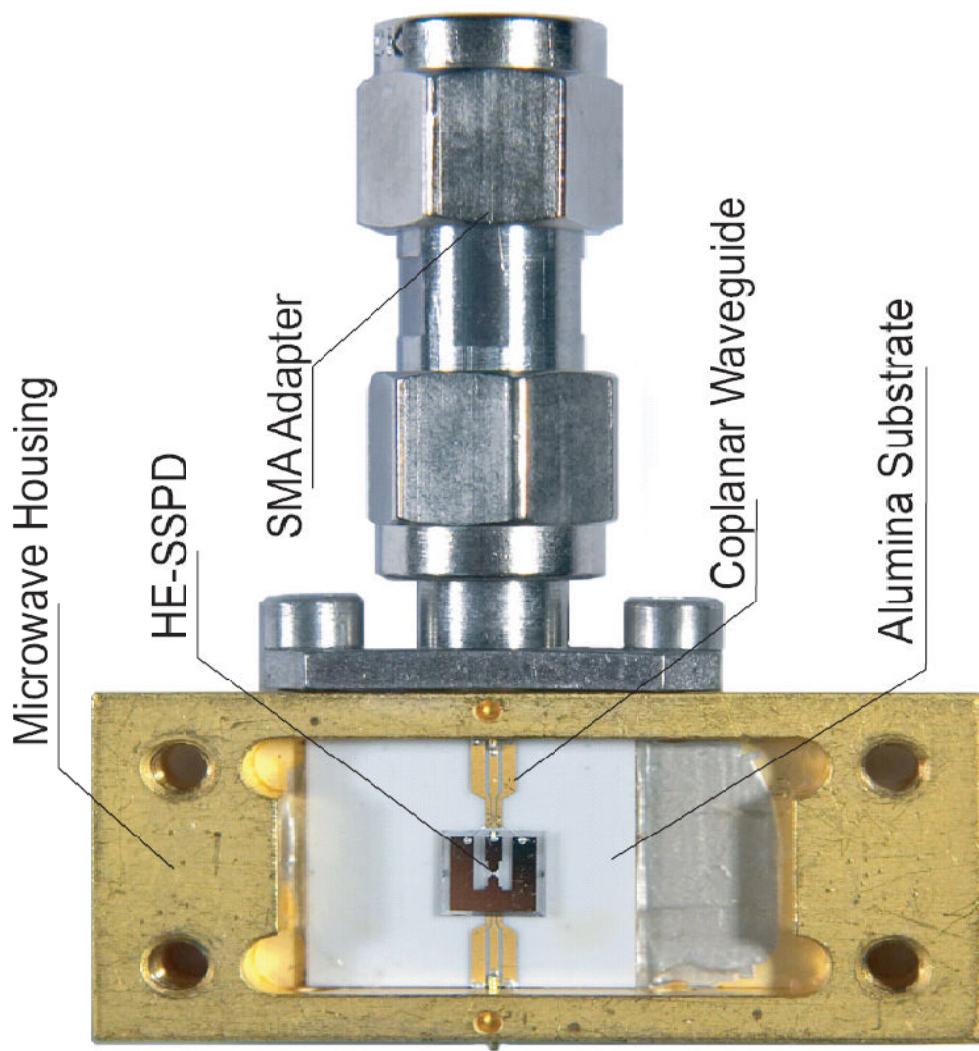


University of Waterloo is developing single photon detectors based on superconducting nanowires



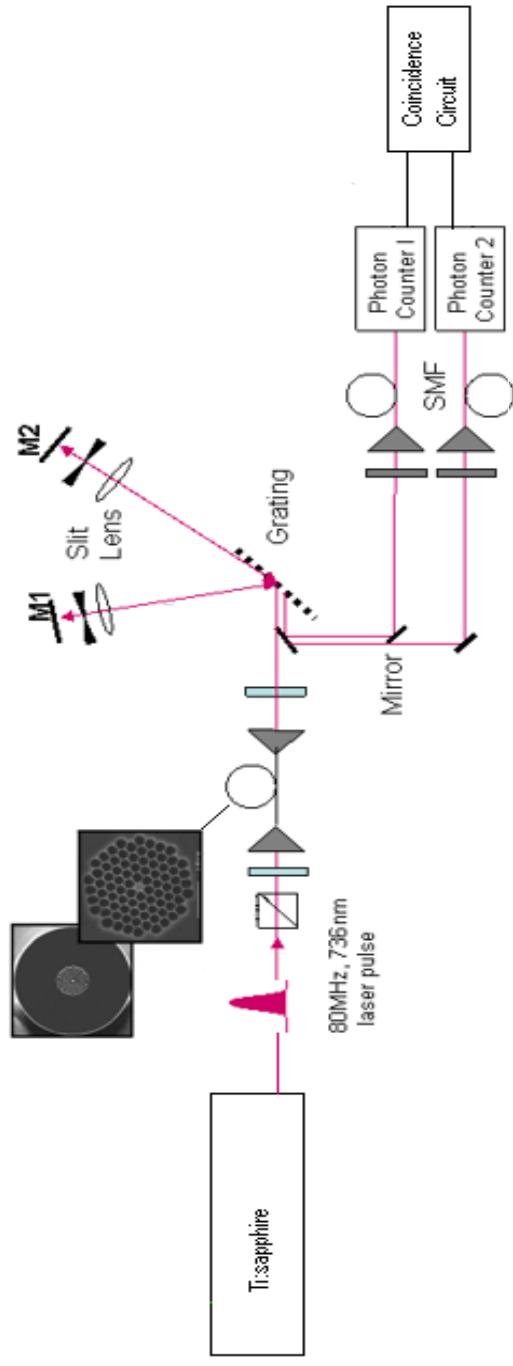


Proper packaging is crucial for best performance of these detectors





Correlated photons can be used to measure quantum efficiencies

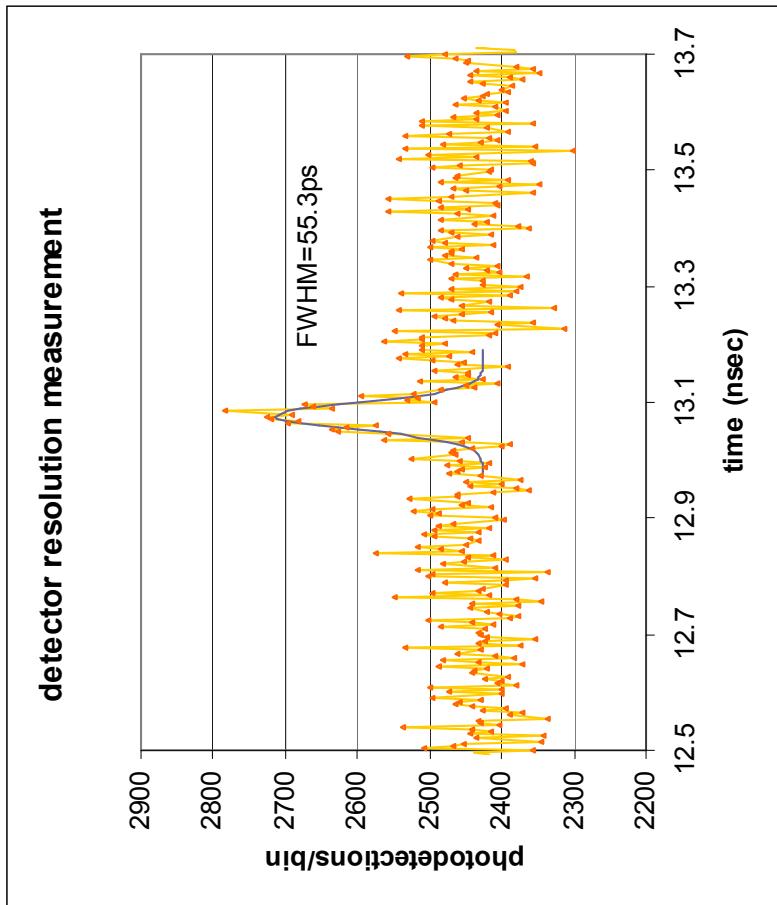
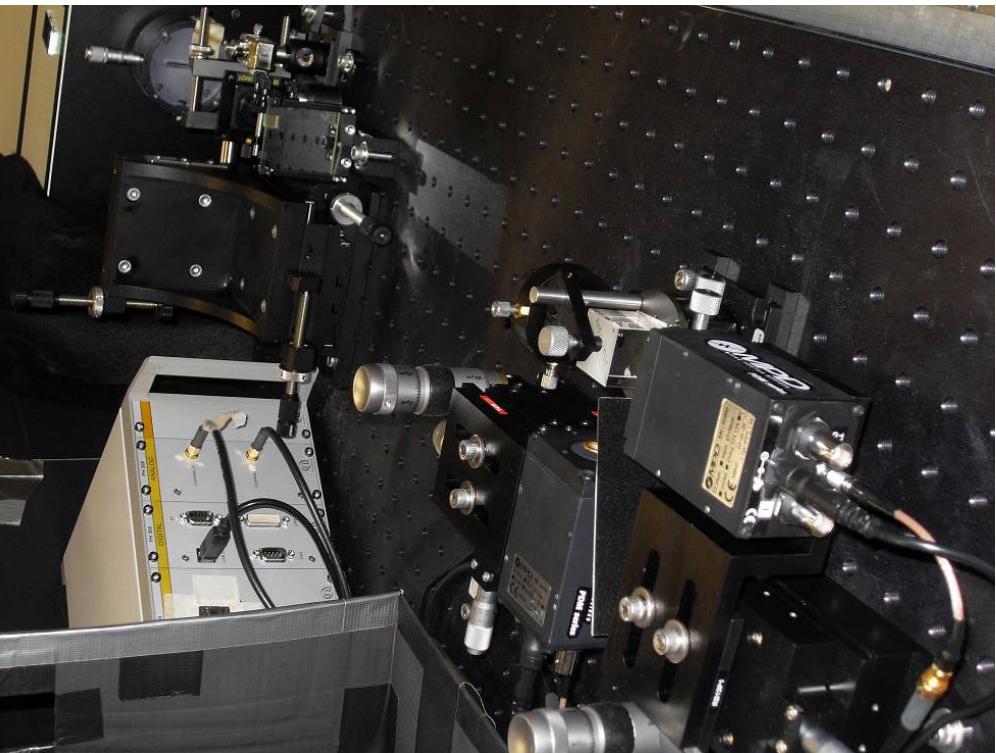


$$N_2 = n_2 N \quad N_C = n_1 n_2 N$$

$$\eta_1 = \frac{N_C}{N_2}$$



This technique can also be used to measure timing jitter



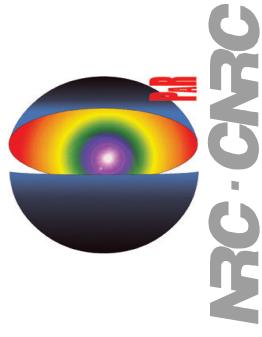


Developed technologies allow NRC-INMS to explore the concept of the quantum candela

Quantum candela*

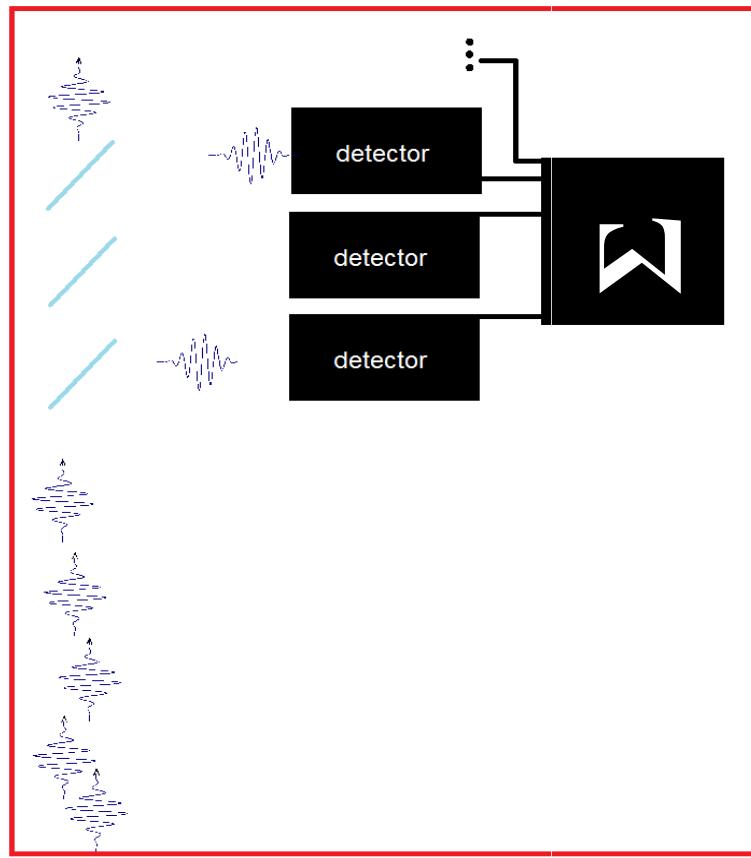
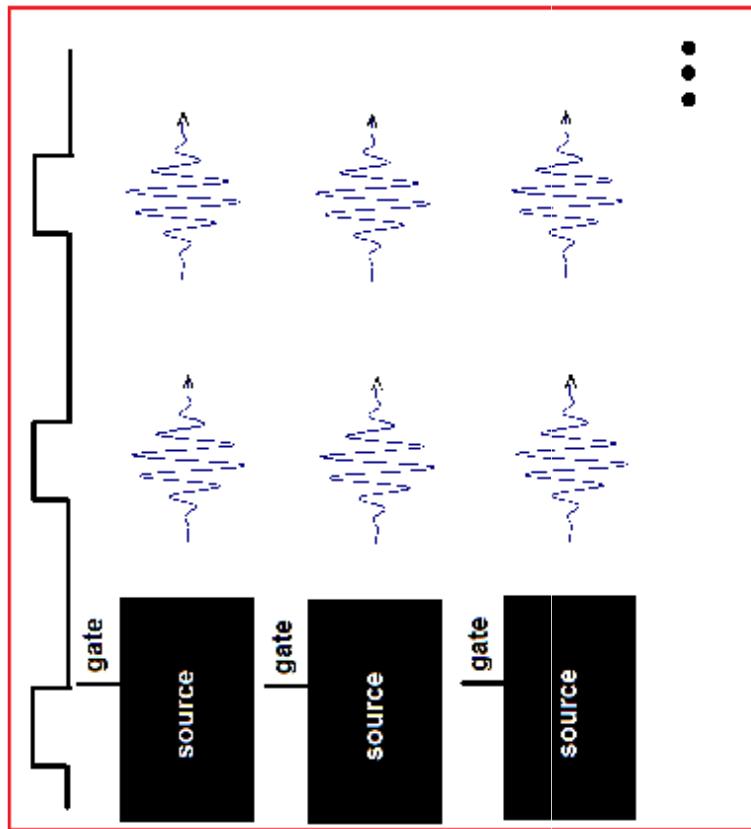
- The candela is the luminous intensity, in a given direction, of a source that emits photons of frequency 540×10^{12} hertz at a rate of 4.092×10^{15} photons per second per steradian in that direction.

*Cheung et al, J Mod Opt, 54 373-396 (2007)





The realization of the quantum candela could be either source based or detector based





Conclusions

- The technology to fabricate photon-on-demand sources is being developed. We will be able to characterize them
- Better single photon detectors are being developed. We will be able to measure performance improvements
- This infrastructure allows us to explore the feasibility of redefining the candela in terms of a countable number of photons

