Quantum Microwave Technology – MASERs and beyond

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NV diamond

Maser oscillation, continuous, solid-state, room temperature

Jonathan Breeze, Neil Alford, et al

[Imperial + UCL] collaboration

https://arxiv.org/abs/1710.07726v1
“Microwaves”

oven

magnetron

radar
Microwaves one the Electromagnetic Spectrum

Maxwell

Hertz

Visible light
\[ \lambda = 0.0001 \text{ cm} \]

Microwaves
\[ \lambda = 10 \text{ cm} \]

Factor of 100,000 in wavelength (or frequency)
Waves behaving badly .... like particles (”quanta”)

Am I an X-ray photon ...? Or a radio photon? Or visible?

Oh hell...! Why worry about all that again...? I'm not even sure if I'm a wave or a particle!

PHOTON SELF-IDENTITY PROBLEMS
Getting Inside Your Head
(with MRI, EPR, Endor ... )

Microwaves refresh the parts wot other photons cannot reach.
Doing “Quantum Optics” (← Quantum Technologies)

Counting/detecting single photons

Energy of a photon

\[ E = \frac{hc}{\lambda} \]

Optical wavelengths:

- Photomultipliers
- Avalanche photodiodes

Microwaves:

100,000 times less energy per photon

Difficult!
The Bad News: Thermal Photons

At room temperature, the number of microwave photons in an electromagnetic cavity @ 10 GHz

\[ \frac{1}{2} \frac{kT}{(hc / \lambda)} = 300 \]
The Good News: Spontaneous Emission

Rate of spontaneous emission
Einstein’s A coefficient (causing shot noise)

\[ A = (\text{constants}) f^3 \]

 extremely low
(too small to care about)
Cooling to Photonic Ground State (at room temperature)

NV diamond

Microwave wave transition with equivalent Boltzmann temperature of ~100 mK
Look to the Heavens!

Sky Temperature

Solid line gives noise floor from space
Dotted line gives noise from earth

Hydrogen line

Beam angle from zenith

Lowest noise radio “window”

Cosmic fireball “floor”

Galactic noise

90°
80°
0°

Earth’s atmospheric noise

Photon noise

10 m 1 m 0.1 mm

Frequency

100 MHz 1 GHz 10 GHz 100 GHz 1 THz 10 THz 100 THz 1 PHz

Wavelength (mm)

CO₂ line

Absorption (dB/km)

Absorption

Galactic noise

Rain

1 mm/h rain

10 mm/h rain

100 mm/h rain

O₂

H₂O

Absorption

Frequency

Sky Temperature

Frequency
Avalanche Photo-detector for Microwave Photons

Main reference:

pentacene:p-terphenyl
Quantum Microwave Technology in a Nutshell:

Every photon’s precious. Every photon counts. If you can count microwaves, in the bank comes large amounts.

picking a pocket or two ...