Inhibition of spontaneus emission: Purcell's landmark paper

B10. Spontaneous Emission Probabilities at Radio Frequencies. E. M. Purcell, *Harvard University.*—For nuclear magnetic moment transitions at radio frequencies the probability of spontaneous emission, computed from

$$A_\nu = (8\pi\nu^2/c^3)h\nu(8\pi^3\mu^2/3h^2) \text{ sec.}^{-1},$$

is so small that this process is not effective in bringing a spin system into thermal equilibrium with its surroundings. At 300°K, for $\nu=10^7$ sec.$^{-1}$, $\mu=1$ nuclear magneton, the corresponding relaxation time would be 5×10^{21} seconds! However, for a system coupled to a resonant electrical circuit, the factor $8\pi\nu^2/c^3$ no longer gives correctly the number of radiation oscillators per unit volume, in unit frequency range, there being now *one* oscillator in the frequency range ν/Q associated with the circuit. The spontaneous emission probability is thereby increased, and the relaxation time reduced, by a factor $f=3Q\lambda^3/4\pi^2V$, where V is the volume of the resonator. If a is a dimension characteristic of the circuit so that $V\sim a^3$, and if δ is the skin-depth at frequency ν, $f\sim\lambda^3/a^2\delta$. For a non-resonant circuit $f\sim\lambda^3/a^3$, and for $a<\delta$ it can be shown that $f\sim\lambda^3/a\delta^2$. If small metallic particles, of diameter 10^{-3} cm are mixed with a nuclear-magnetic medium at room temperature, spontaneous emission should establish thermal equilibrium in a time of the order of minutes, for $\nu=10^7$ sec.$^{-1}$.

Proceedings of the American Physical Society

Minutes of the Spring Meeting at Cambridge, April 25–27, 1946

ABSTRACTS OF CONTRIBUTED PAPERS

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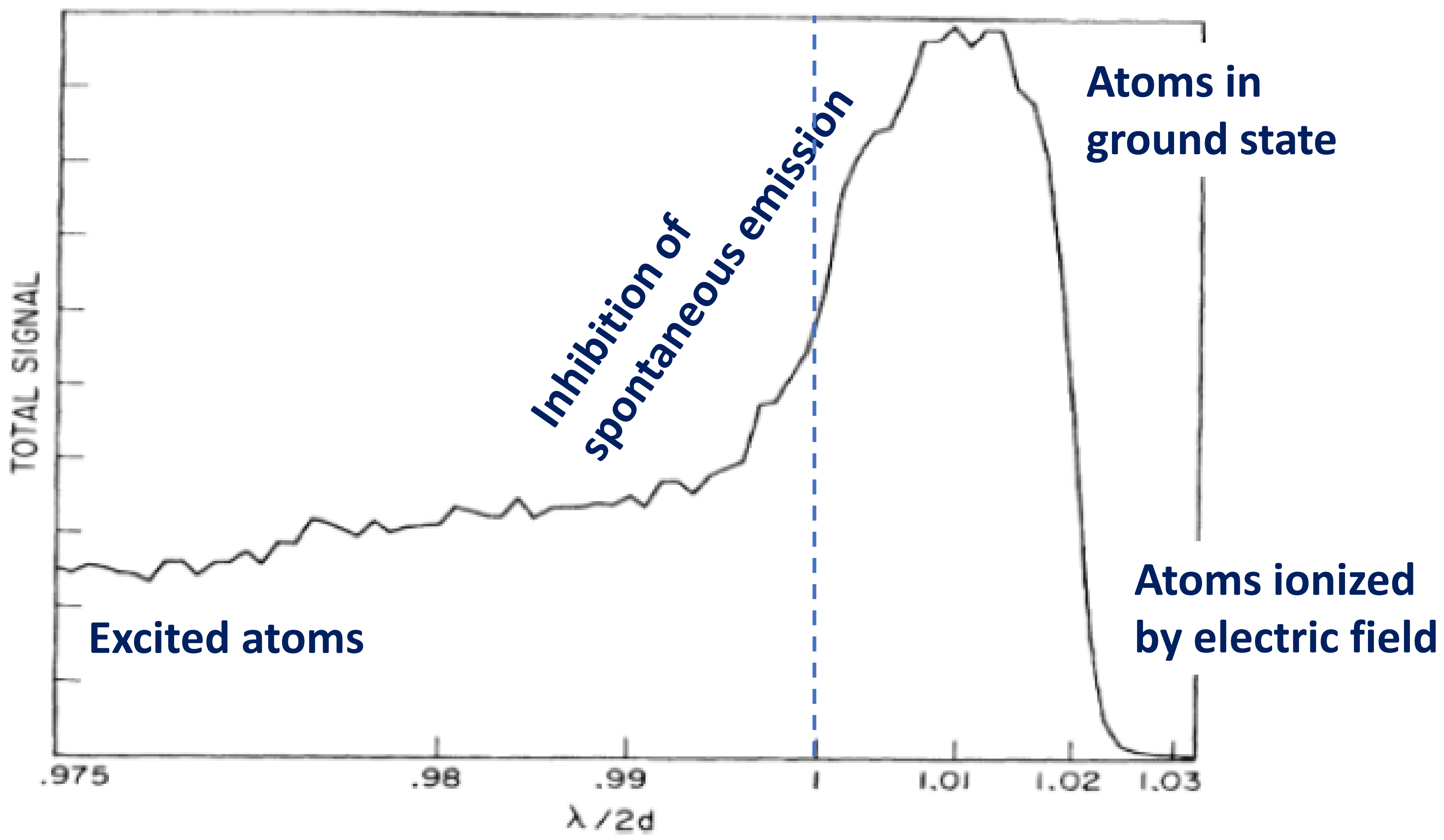
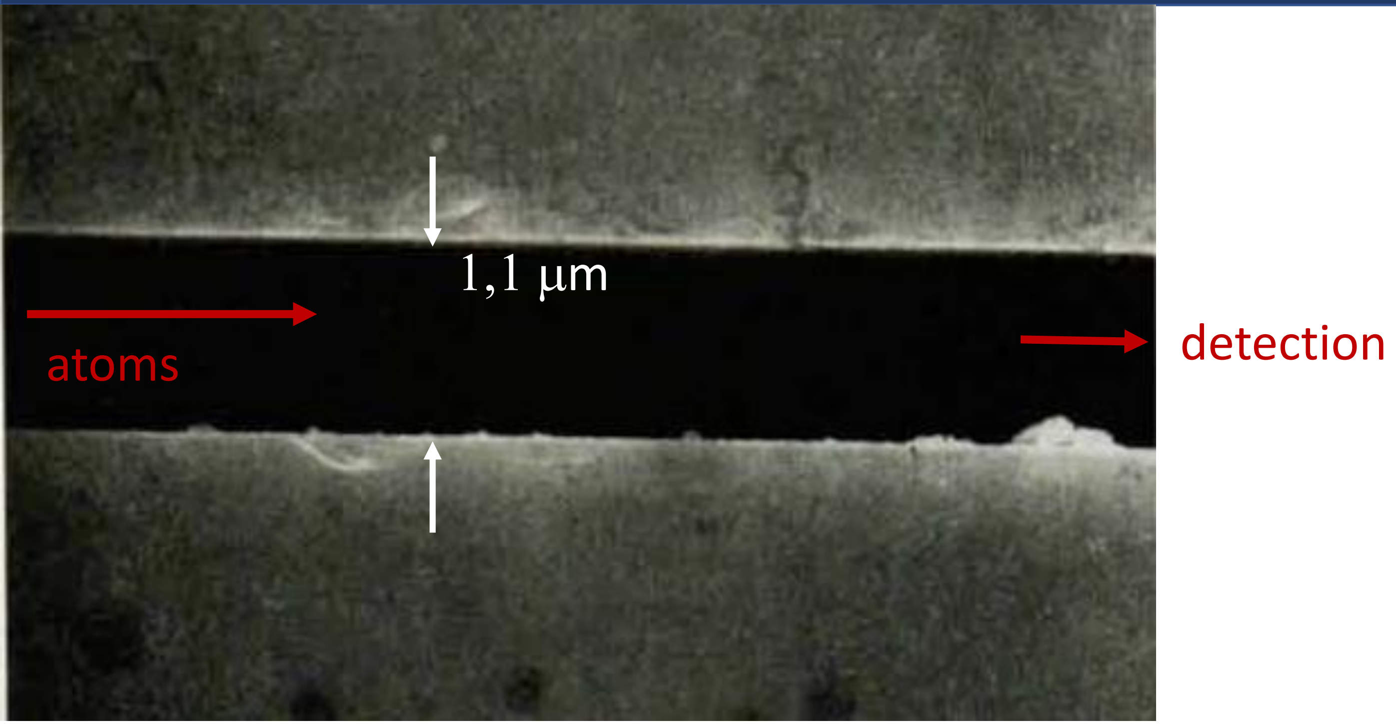
B9. Measurement of Magnetic Resonance Absorption by Nuclear Moments in a Solid. R. V. POUND AND E. M. PURCELL, *Harvard University*, AND H. C. TORREY, *Radiation Laboratory, Massachusetts Institute of Technology*.—We have observed resonance absorption at 29.8 mc/sec. by magnetic moments of protons in solid paraffin at room temperature. A capacitatively loaded coaxial line resonator, filled with paraffin, was placed in a large magnet with the steady magnetic field perpendicular to the r-f magnetic field. The resonator formed one arm of an r-f bridge. The unbalance-signal produced by a small change in resonator transmission was amplified, detected and indicated on a meter. Resonance absorption occurred at a field of 7100 gauss, in agreement, within the probable error of our calibrations, with the known gyromagnetic ratio of the proton. The width of the absorption line, at half value, was 10 gauss, perhaps due in part to field inhomogeneities, and the maximum diminution in cavity transmission was 0.4 percent. The integrated line strength is in agreement with the theoretical prediction. The relaxation time was less than one minute, contrary to previous predictions of several hours. A more uniform and controllable field, more flexible circuit and detection of an a.c. component in the resonator output, coherent with modulation of the steady field would allow the method to be applied for a wide range of gyromagnetic ratios and nuclear concentrations.

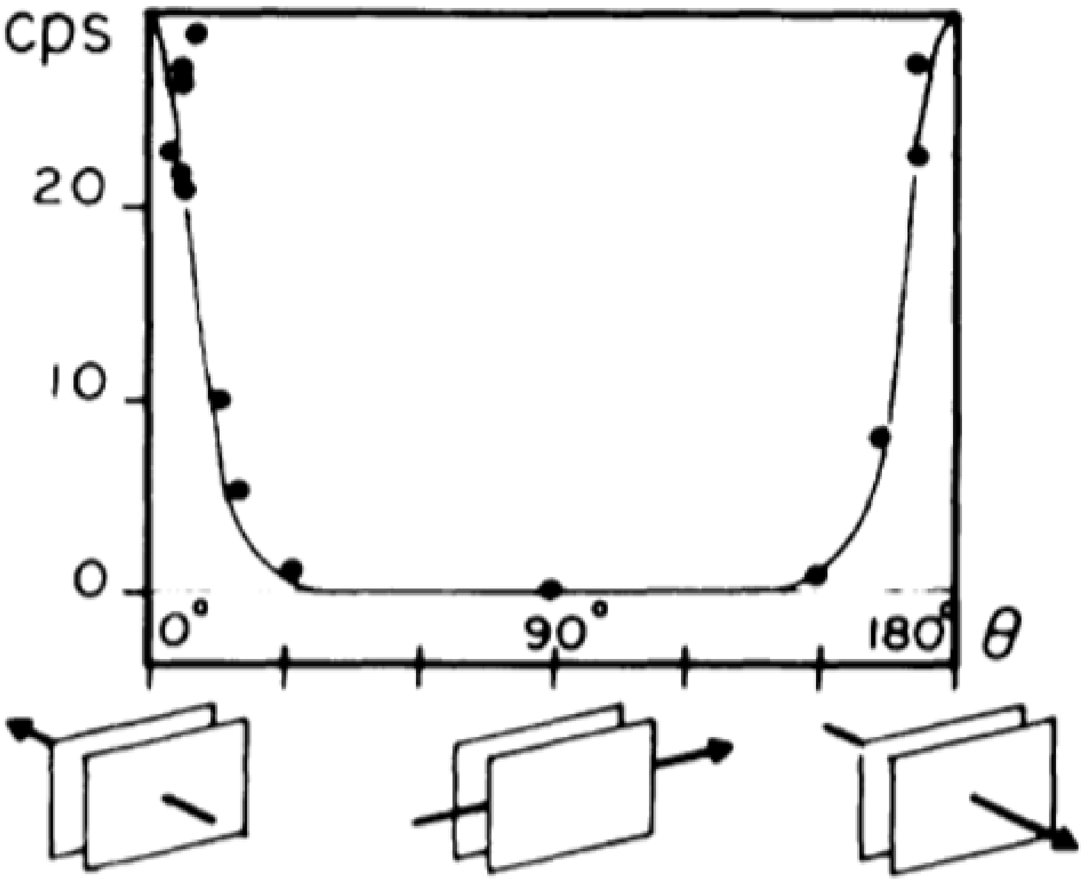
In the same issue (on the same page), an abstract about his Nobel-winning work on NMR

Experiment by Dan Kleppner (MIT, 1983)

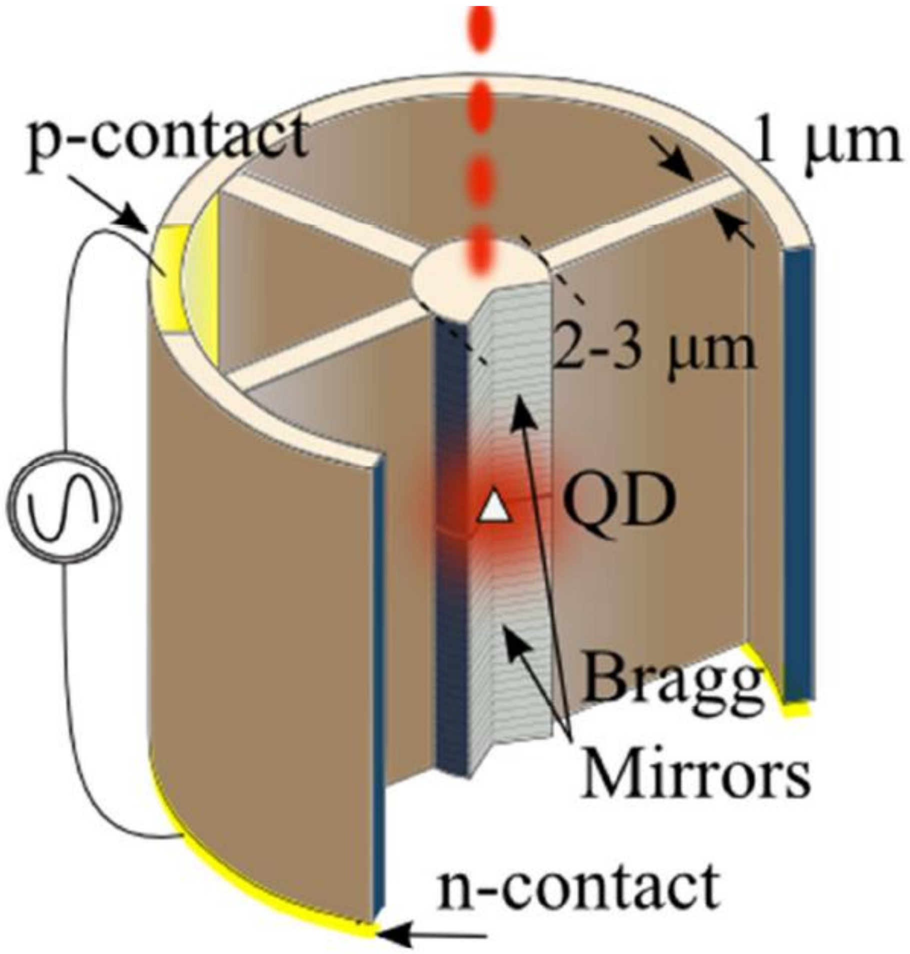


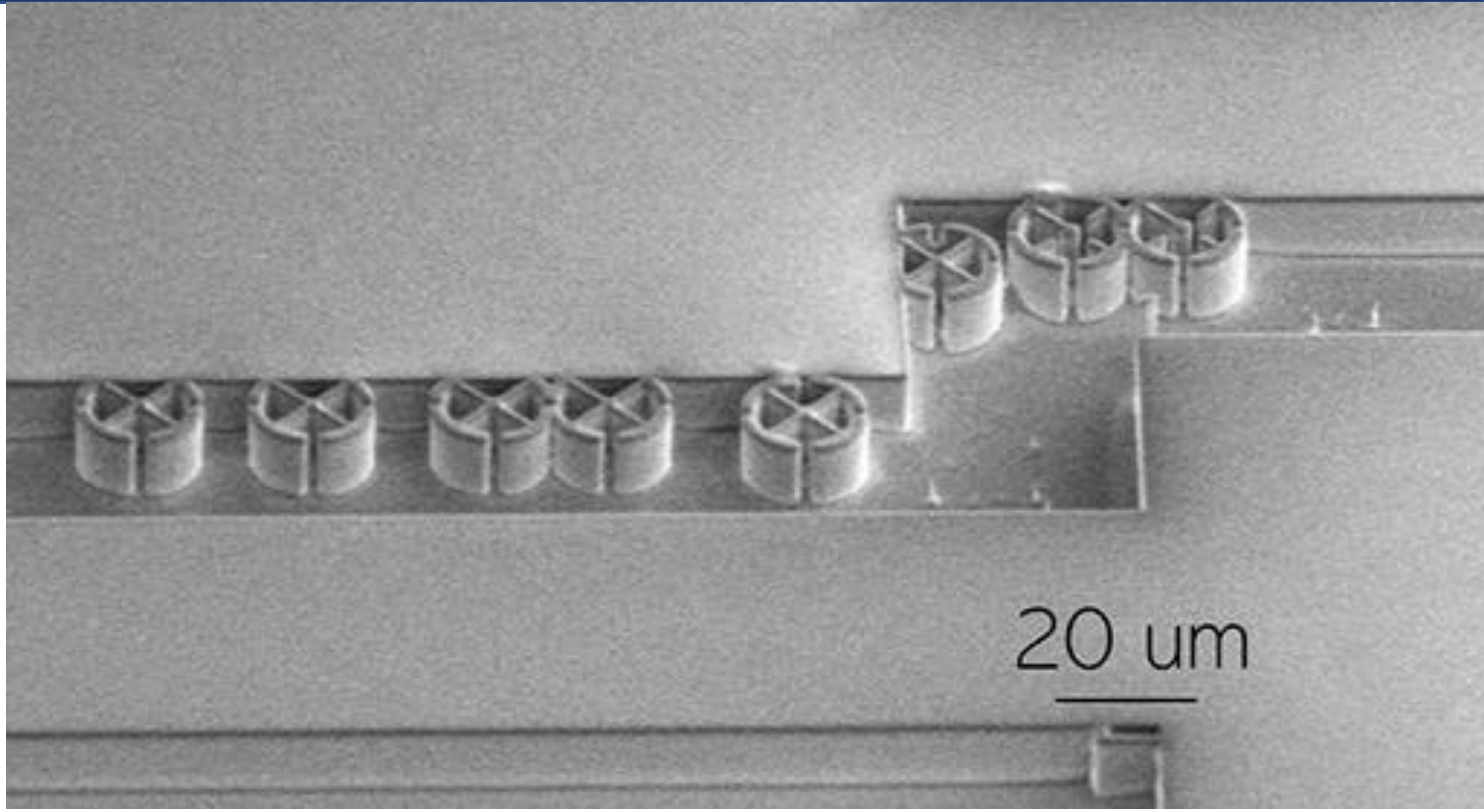
Experiment by Serge Haroche (Yale, 1984)





QUANDELA : a quantum start-up





Quantum Communication & Information

The Casimir force

Sparnaay, M. J. 1958

Physica XXIV 751–764

MEASUREMENTS OF ATTRACTIVE FORCES BETWEEN FLAT PLATES

by M. J. SPARNAAY

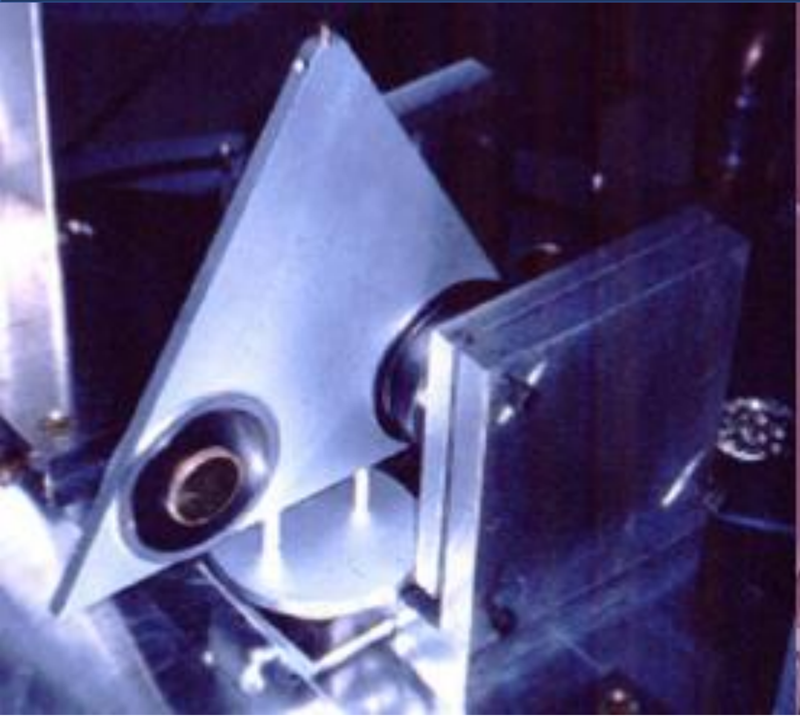
Philips Research Laboratories, N.V. Philips' Gloeilampenfabrieken, Eindhoven, Nederland

Abstract

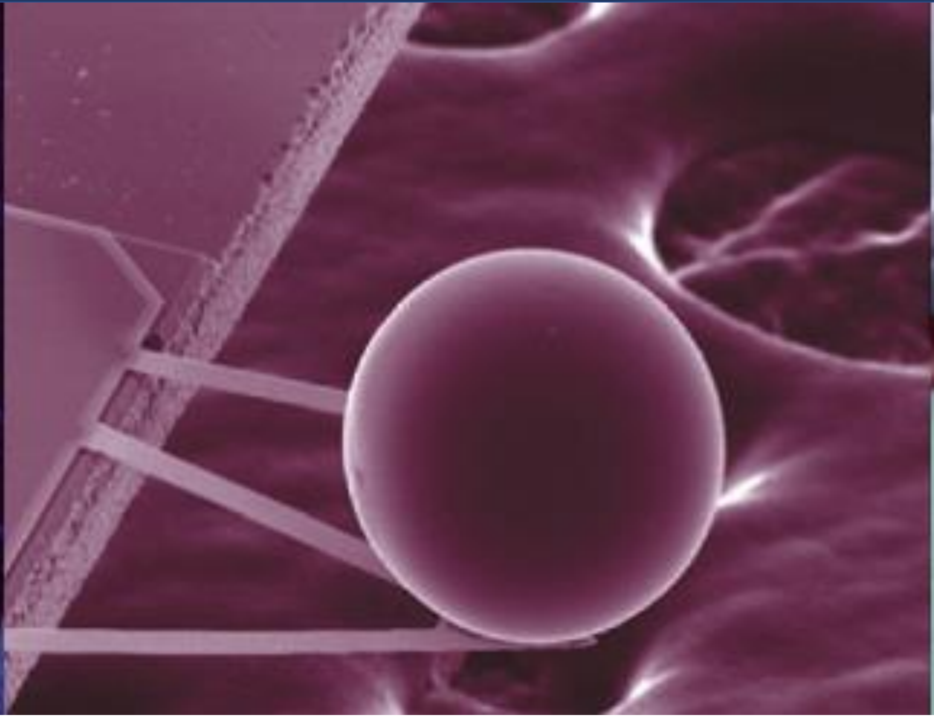
Results of experiments concerning attractive forces between flat metal plates, and a description of the apparatus used, are given. The observed attractions do not contradict Casimir's theoretical prediction.

An explanation of results of earlier measurements made by the author on the attraction between clean, and also between silvered glass and quartz plates, all brought in an ionized atmosphere, is suggested. These results were due to differences in the surface potentials of the opposing plates.

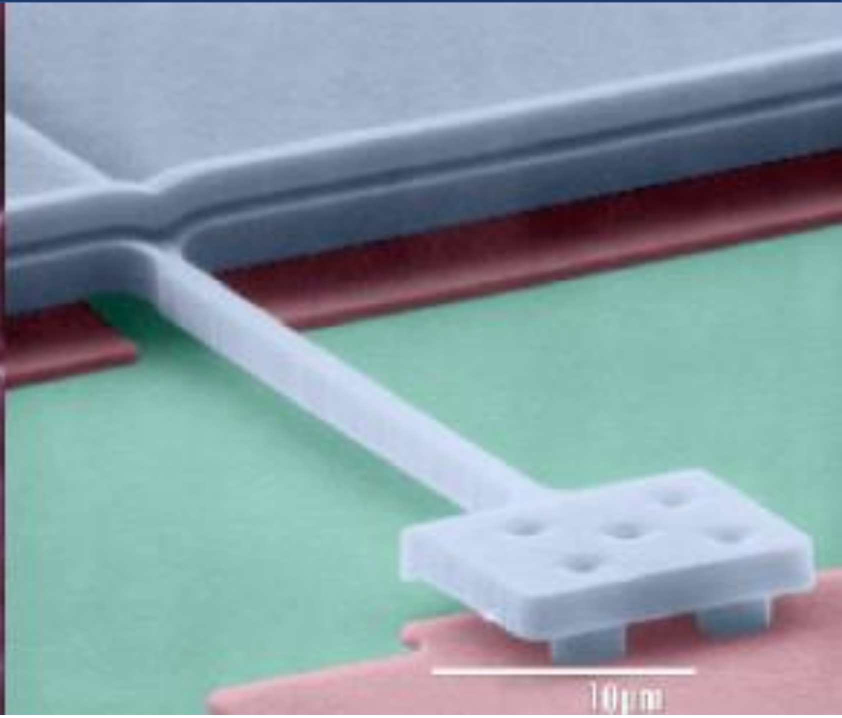
The Casimir force



Onofrio *et al.*
Plane-plane geometry
Dynamic detection

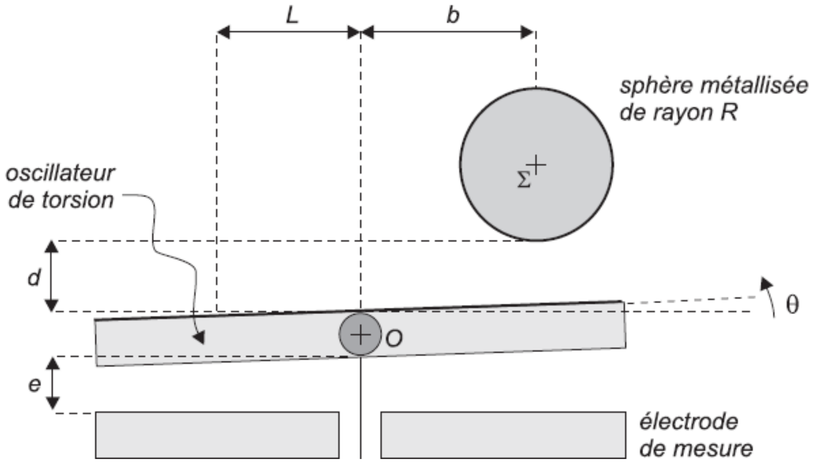


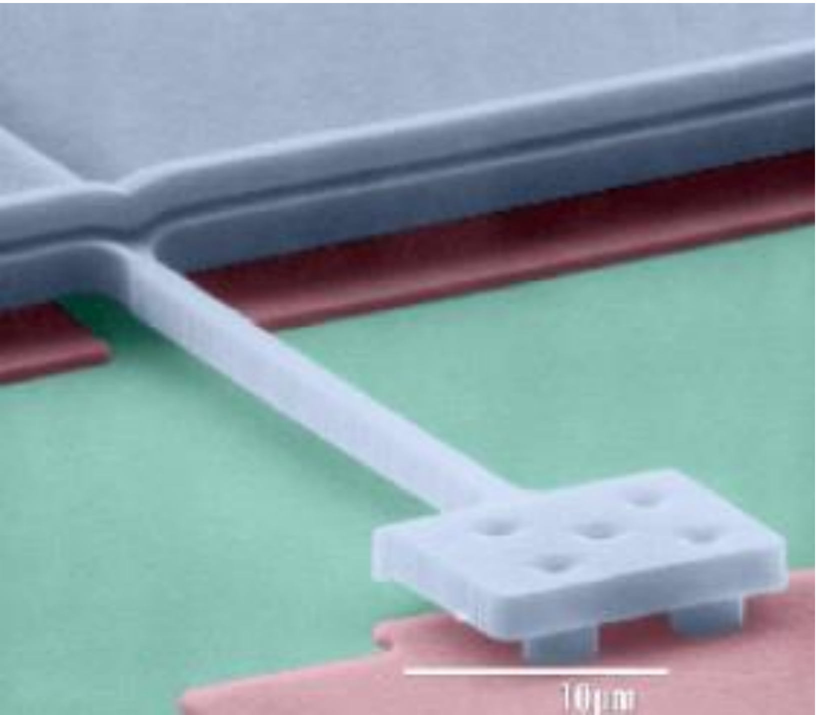
Mohideen *et al.*
Plane-sphere geometry
DC detection



Mohideen *et al.*
Plane-sphere geometry
Torsion oscillator
Dynamic detection

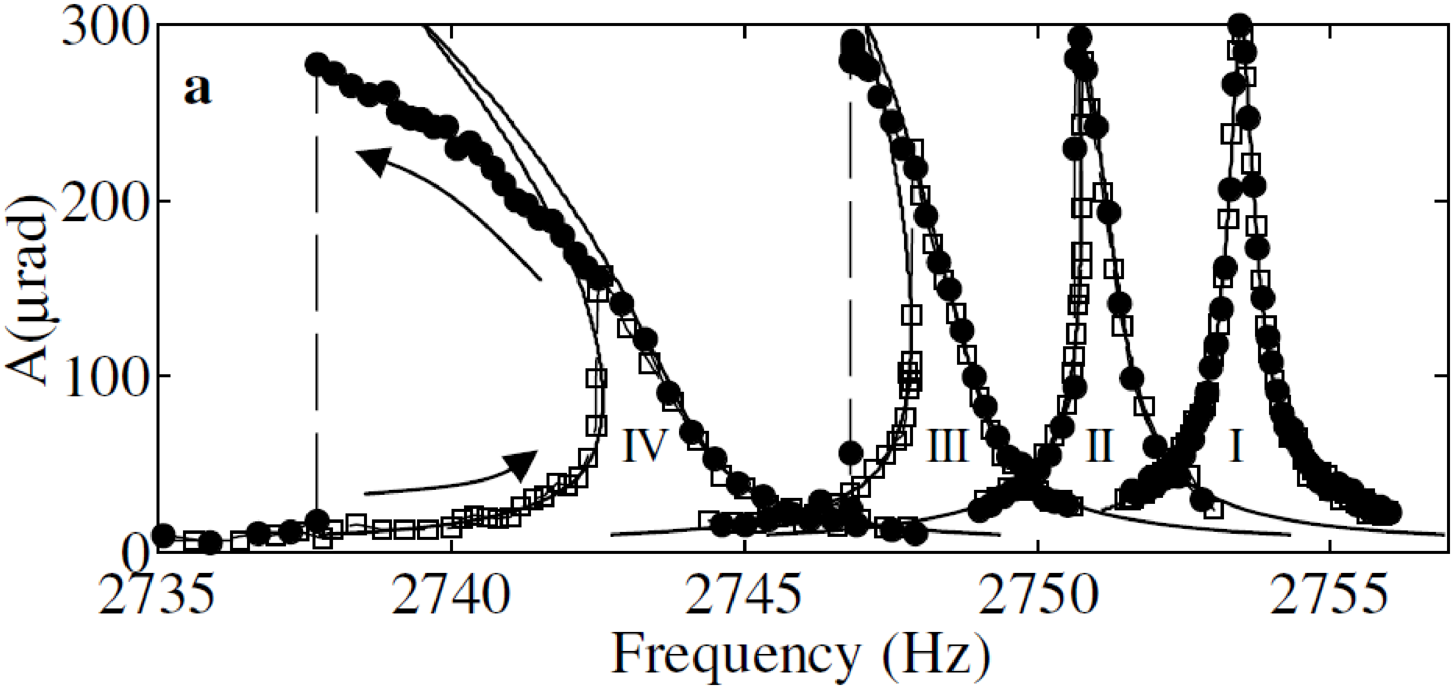
The Casimir force and mechanical oscillators (PRL 2001)



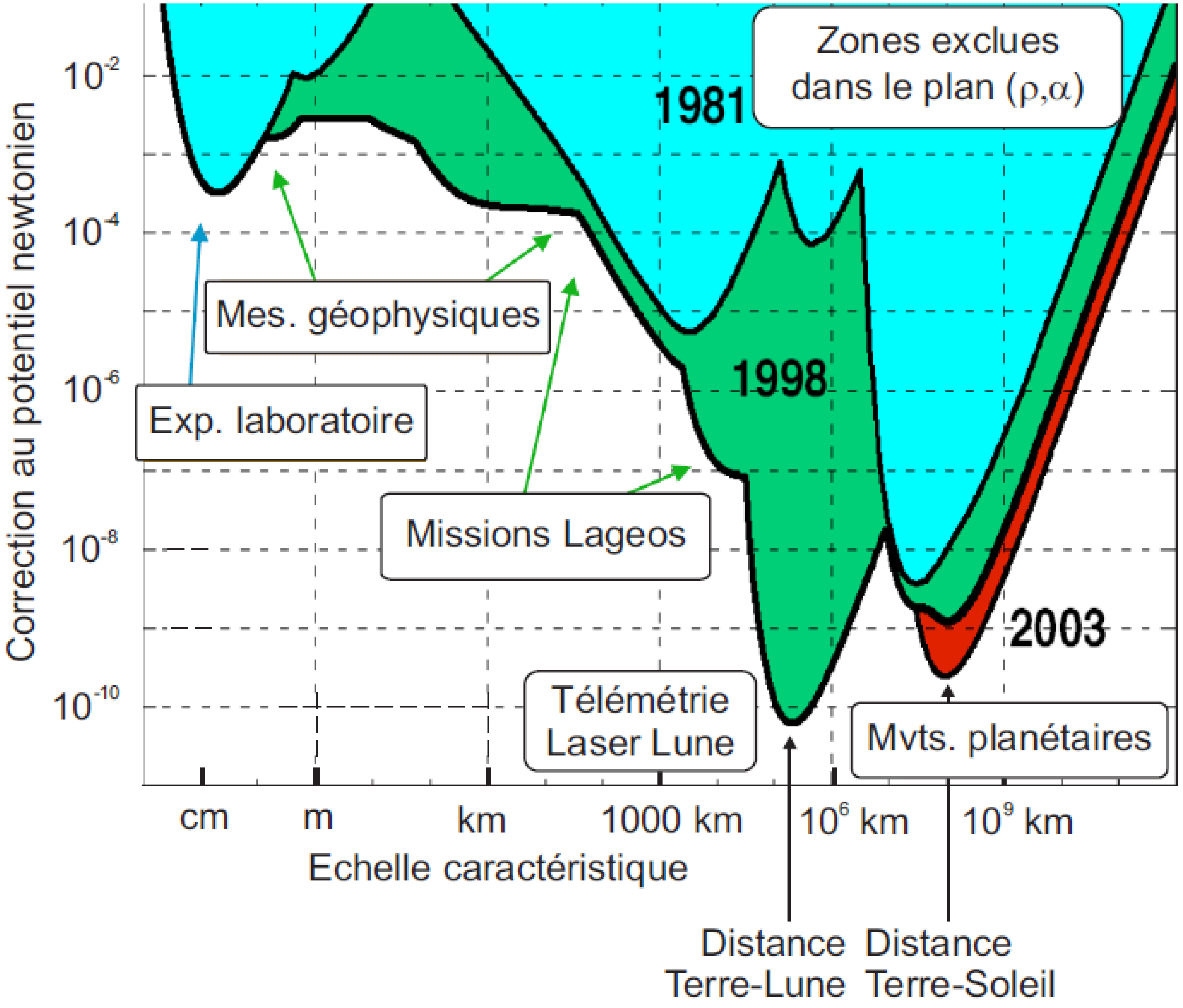


Nonlinear Micromechanical Casimir Oscillator

H. B. Chan,* V. A. Aksyuk, R. N. Kleiman, D. J. Bishop, and Federico Capasso†

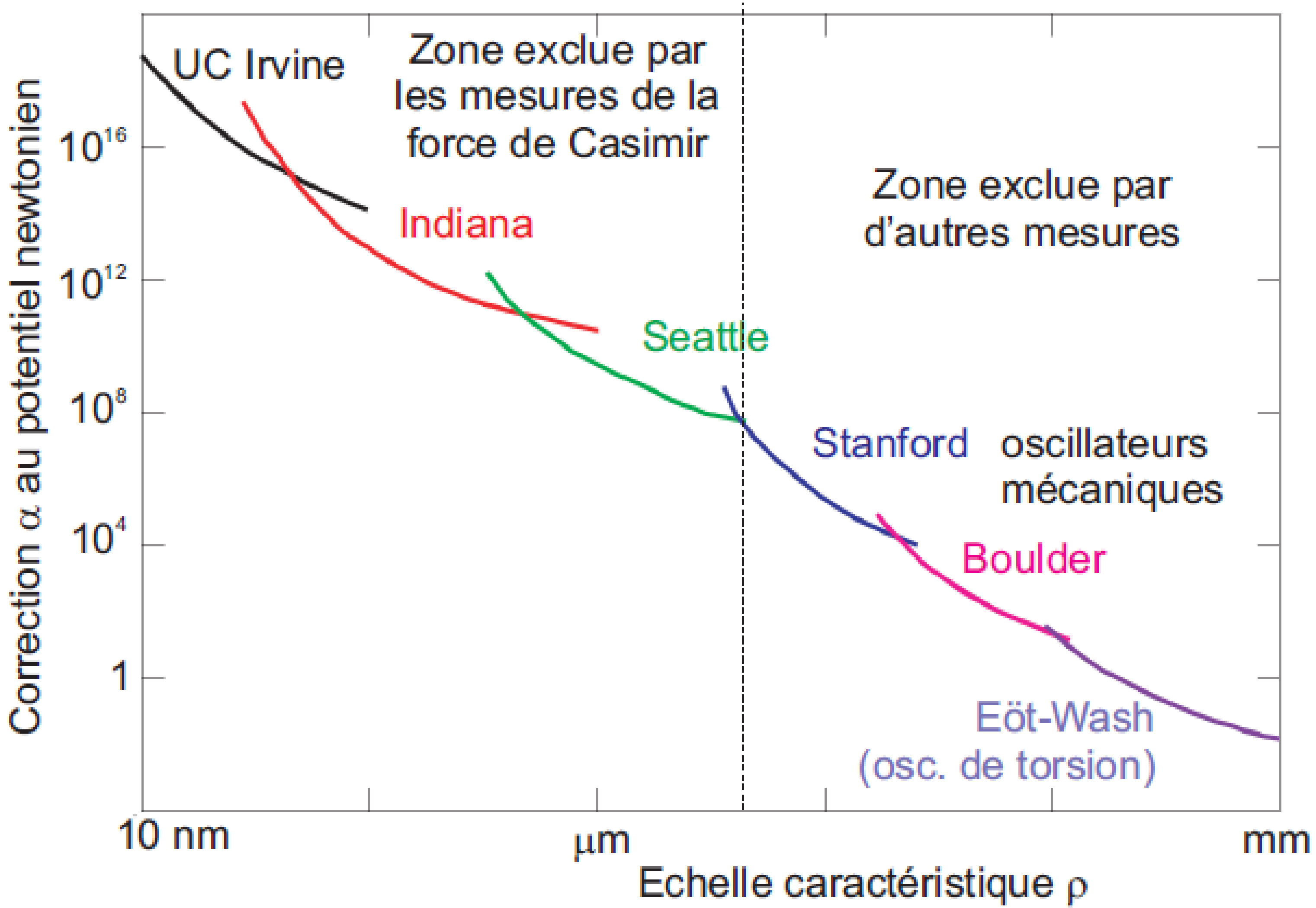


The Casimir force and Newtonian gravitation



$$V(r) = -\frac{Gm_1m_2}{r}\left(1 + \alpha e^{-r/\rho}\right)$$

The Casimir force and Newtonian gravitation



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Modifying Chemical Landscapes by Coupling to Vacuum

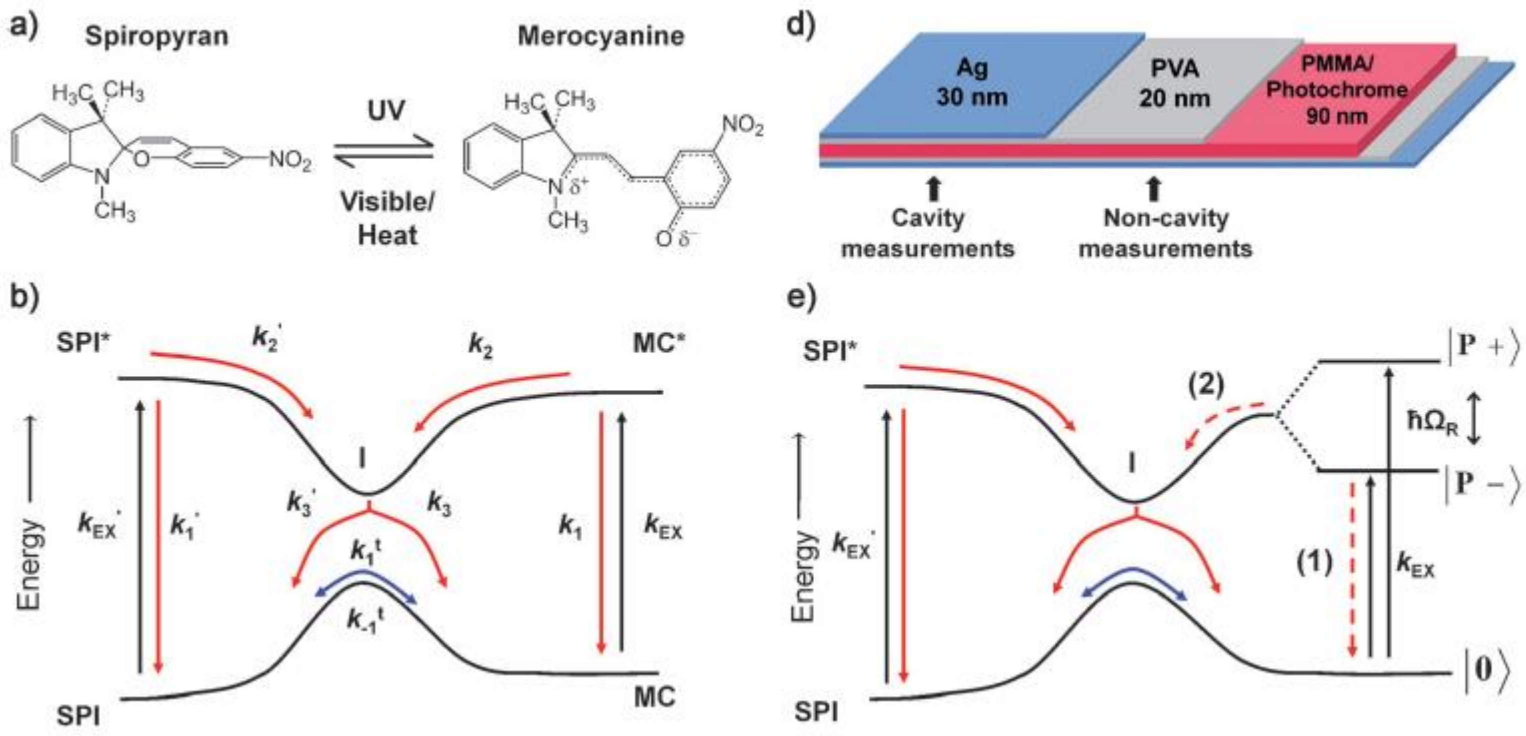
Angewandte Communications

Quantum Electrodynamics

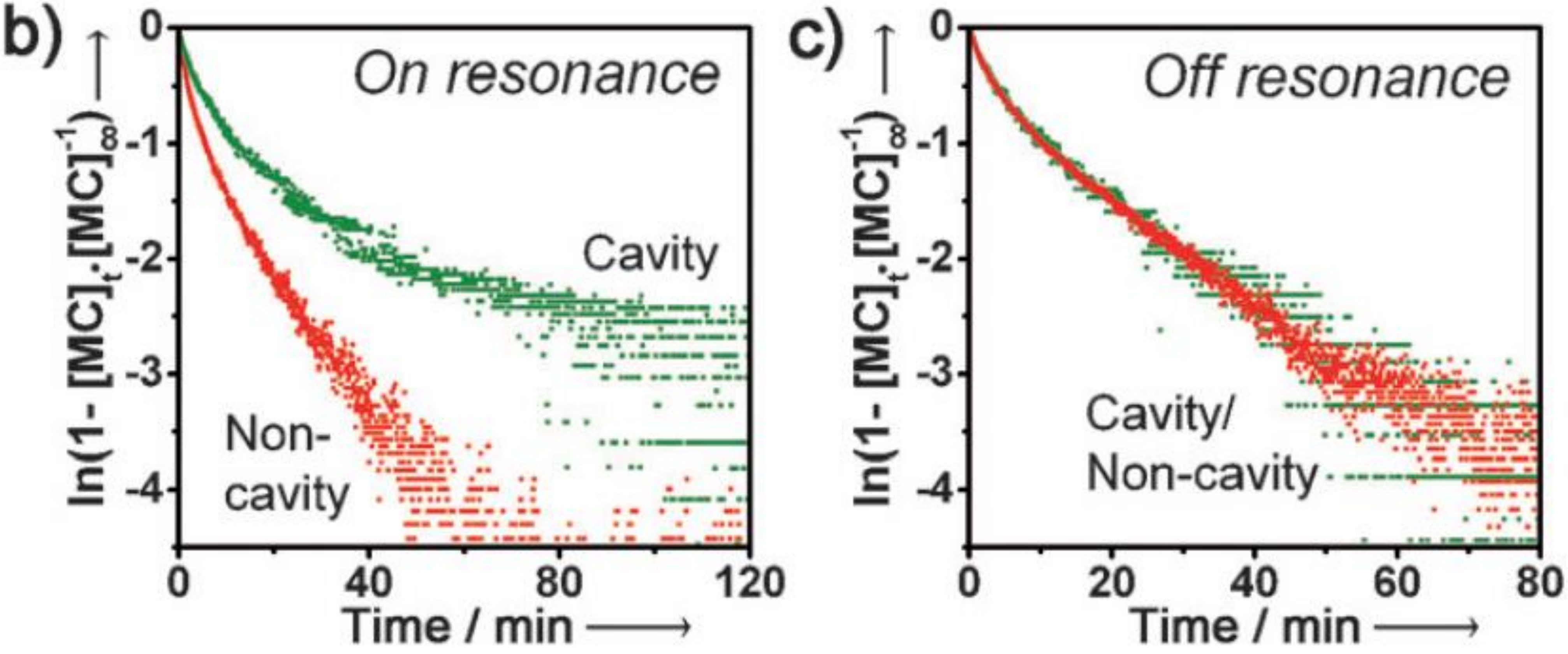
DOI: 10.1002/anie.201107033

Modifying Chemical Landscapes by Coupling to Vacuum Fields**

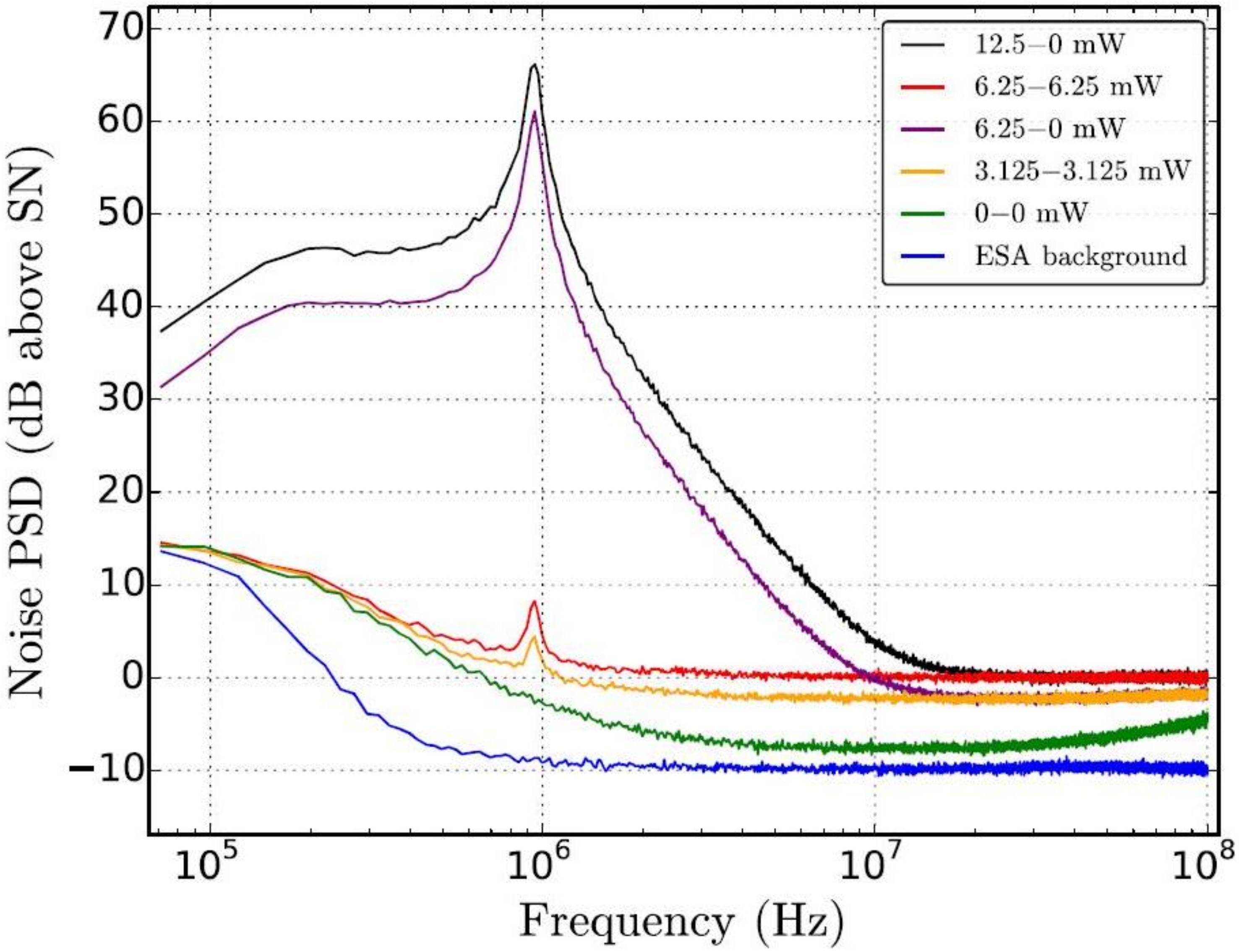
*James A. Hutchison, Tal Schwartz, Cyriaque Genet, Eloïse Devaux, and Thomas W. Ebbesen**



Modifying Chemical Landscapes by Coupling to Vacuum



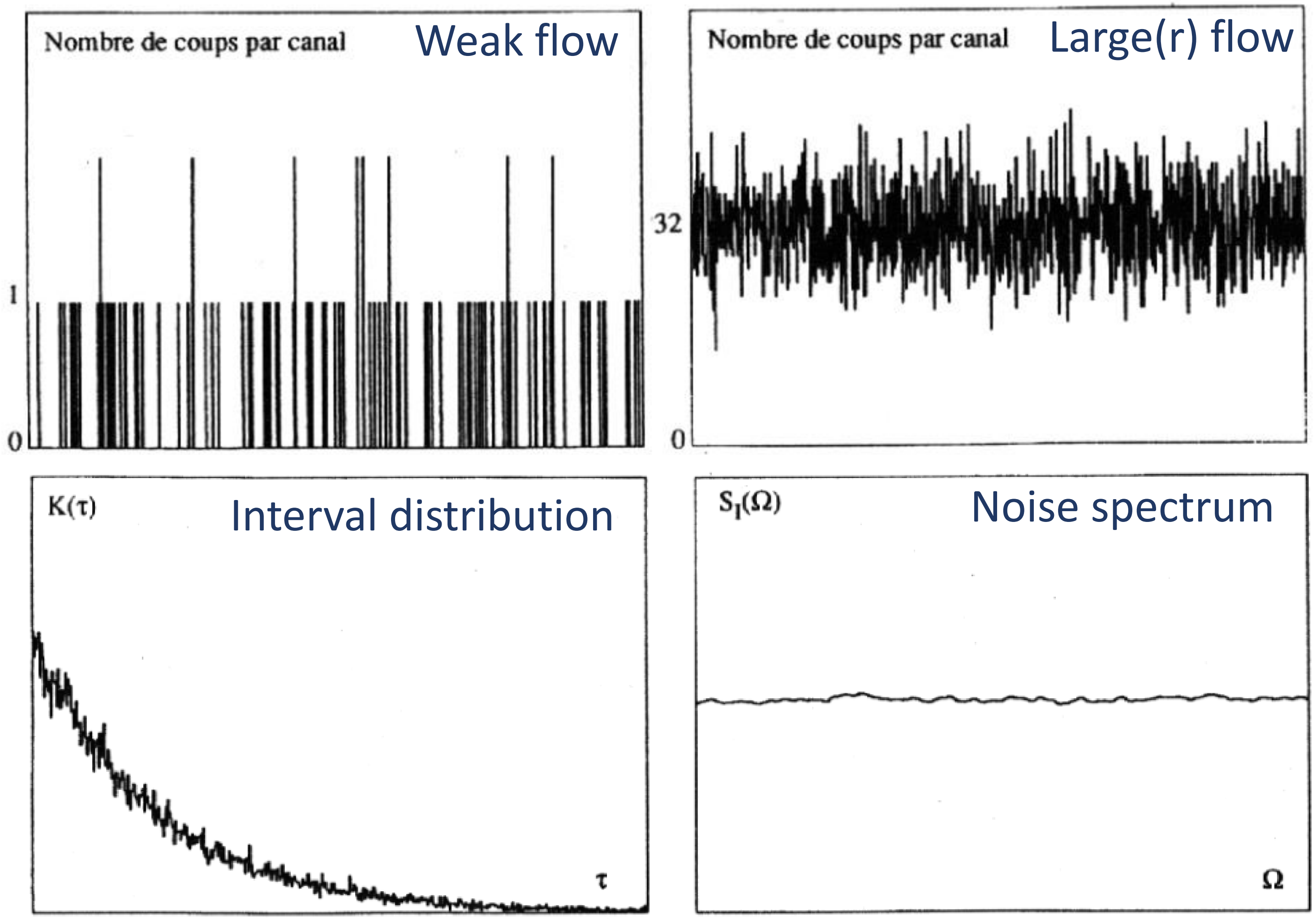
The intensity noise of a laser



Typical intensity noise of a 2-W Nd:YAG laser:

- Relaxation oscillation around 1 MHz
- Classical noise below a few MHz
- Flat noise level above 10 MHz
- Scaling law I^2 at low frequency
- Scaling law I at high frequency
- Same noise for +/- detection

The intensity noise of a laser



Even a basic model can do the job

Rate of detected photons:

$$\dot{n}(t) = \sum_i \delta(t - t_i)$$

Obviously NOT good enough
to describe phase measurements

S. Reynaud, Ann. Phys. (France) **15**, 63 (1990)

Interlude: Amplitude and phase modulations

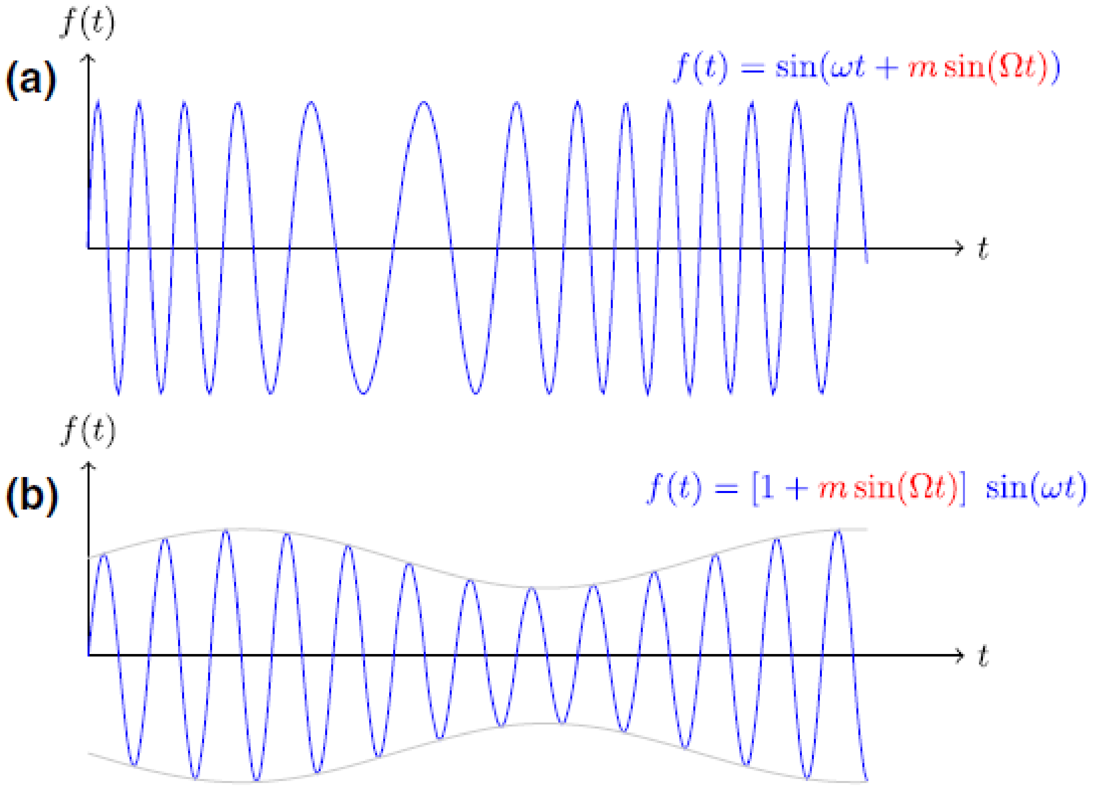
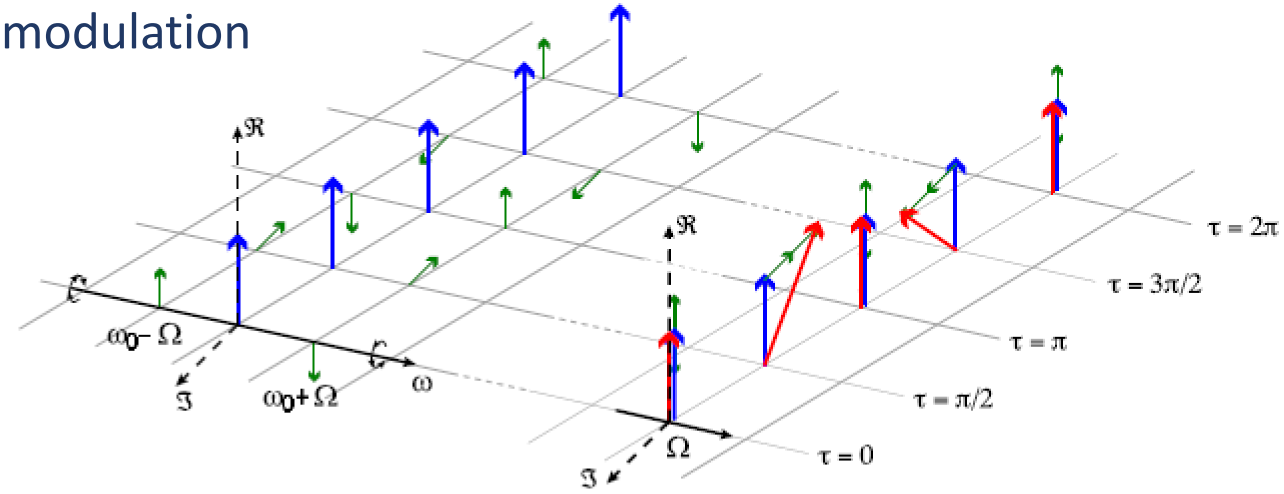


Fig. 17 Example traces for phase and amplitude modulation: the *upper plot* **a** shows a phase-modulated sine wave and the *lower plot* **b** depicts an amplitude-modulated sine wave. Phase modulation is characterised by the fact that it mostly affects the zero crossings of the sine wave. Amplitude modulation affects mostly the maximum amplitude of the wave. The equations show the modulation terms in *red* with m the modulation index and Ω the modulation frequency

C. Bond, D. Brown, A. Freise and K.A. Strain,
ITF techniques for gravitational-wave detection,
Living Reviews in Relativity 19:3 (2016)

Amplitude and phase modulations: sideband approach

Phase modulation

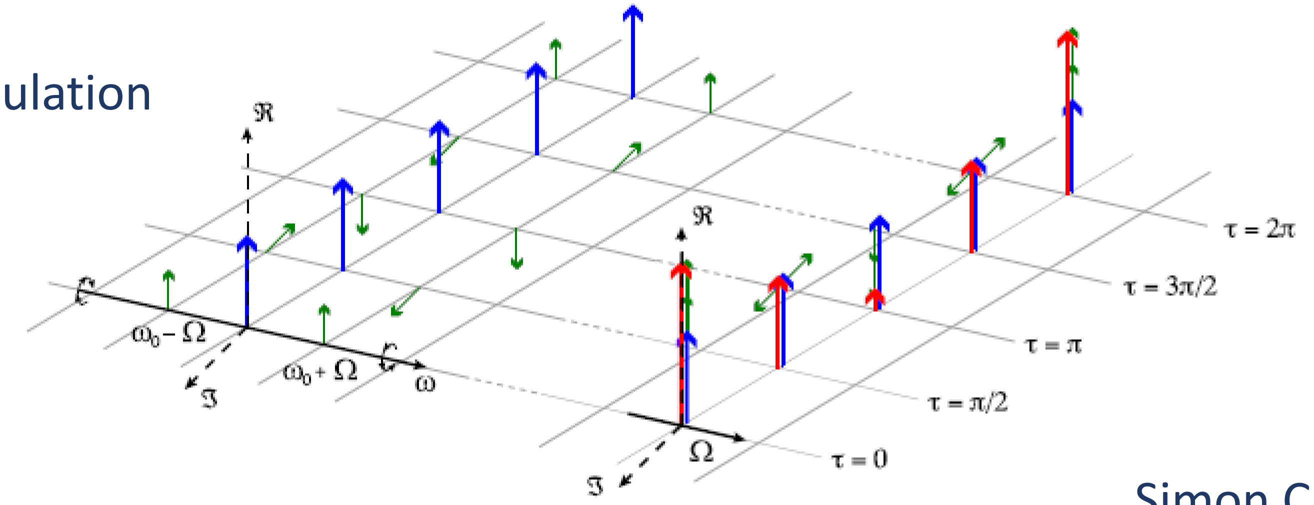


Carrier

Sidebands

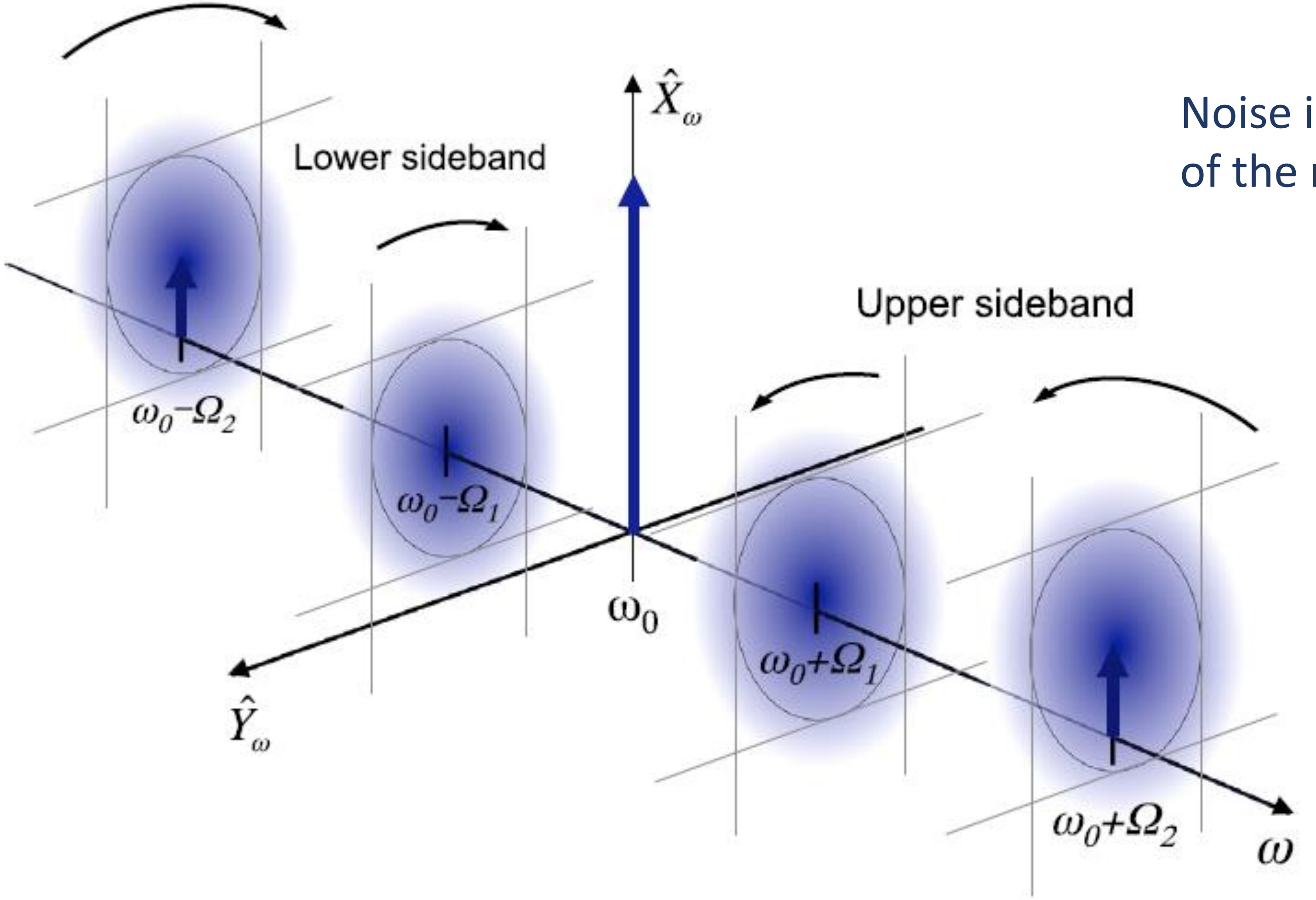
Total E field

Amplitude modulation



Simon Chelkowski, PhD Hannover 2007

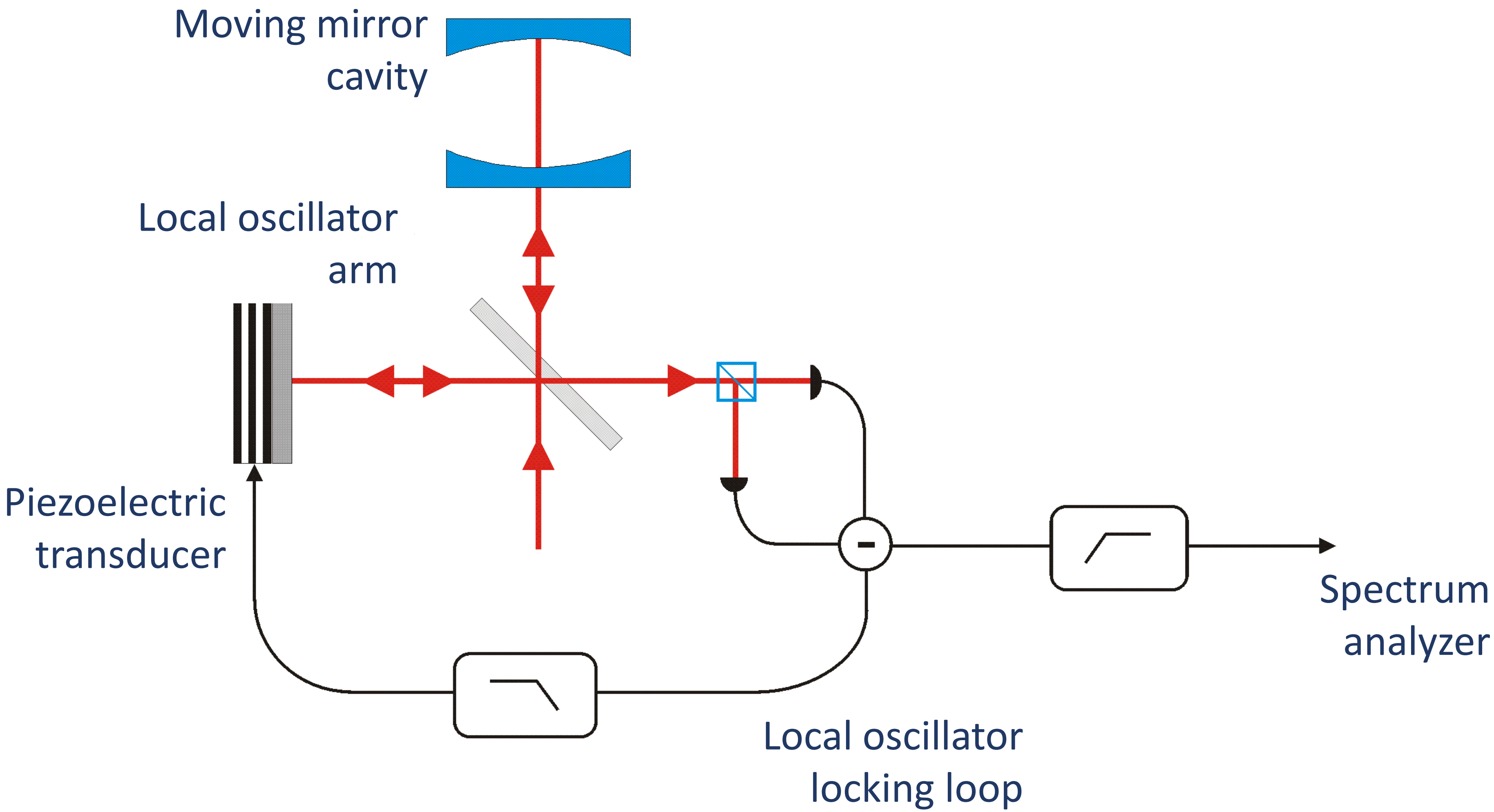
Quantum noise: sideband approach



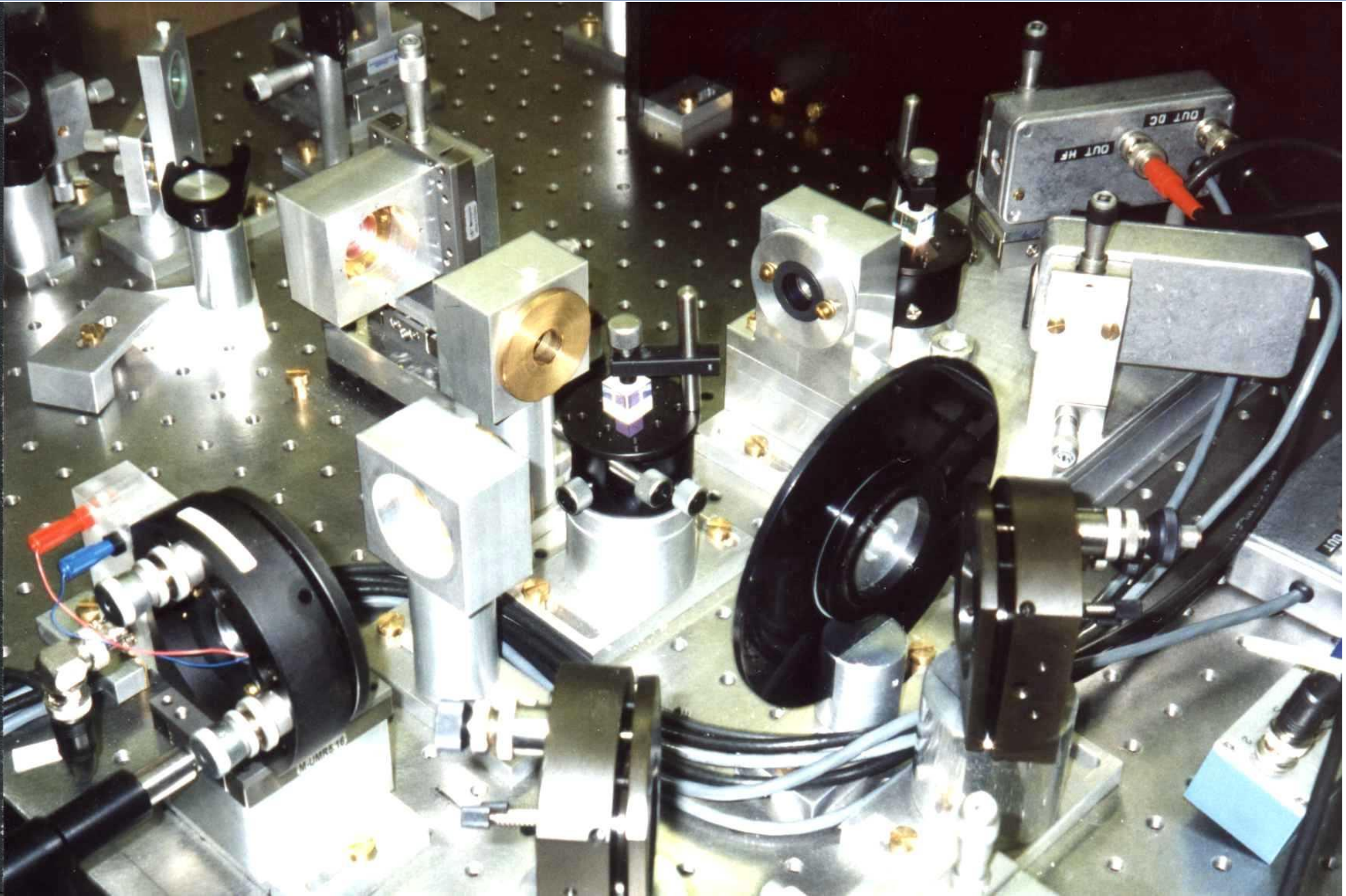
Noise in X[Ω] and Y[Ω] is a sum of the noises at ω_0-Ω and ω_0+Ω

Roman Schnabel,
Squeezed states of light and their applications in laser interferometers,
Physics Reports **684**, 1 (2017)

Homodyne detection



Homodyne detection: practical implementation



Polarization optics (PBS, waveplates…)

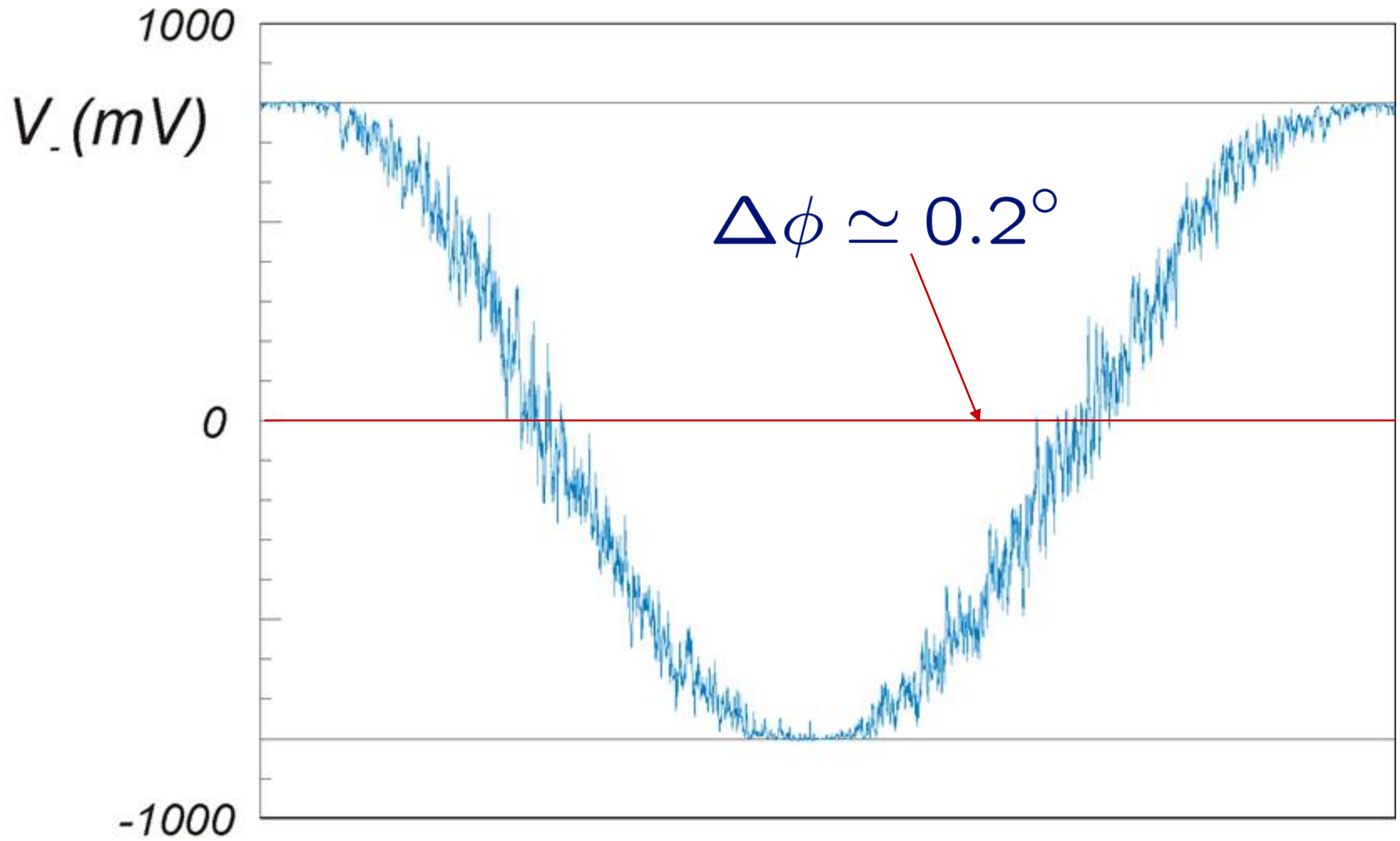
Photodiodes give:

- LF signal (below 10 kHz): quadrature locking
- HF signal (above 10 kHz): quantum optics signal

LO Feedback loop:

- Piezo for intermediate frequencies (1-µm range)
- Piezomotor for low frequencies (1-cm range)

Homodyne detection: results



Time (about 30 minutes)

Very slow T drifts

Higher frequency noise (bus, people…)