

Calculating the Casimir Force on MEMS and NEMS

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The Casimir Force

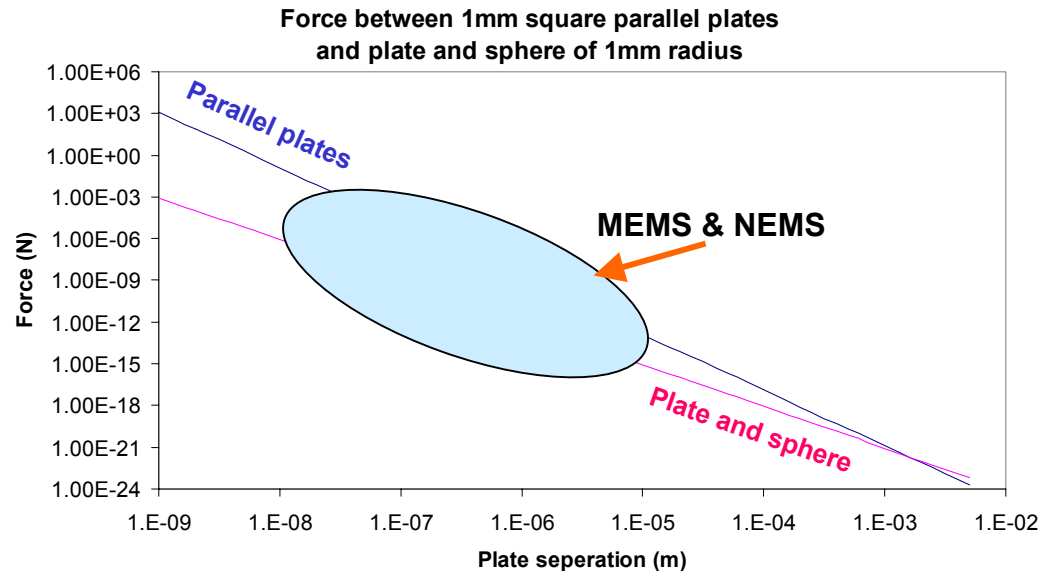
Arises from the interaction of quantum fluctuations (zero point energy) with real world material objects.

The force increases dramatically as the distance between objects becomes less than 1 micron

For example:

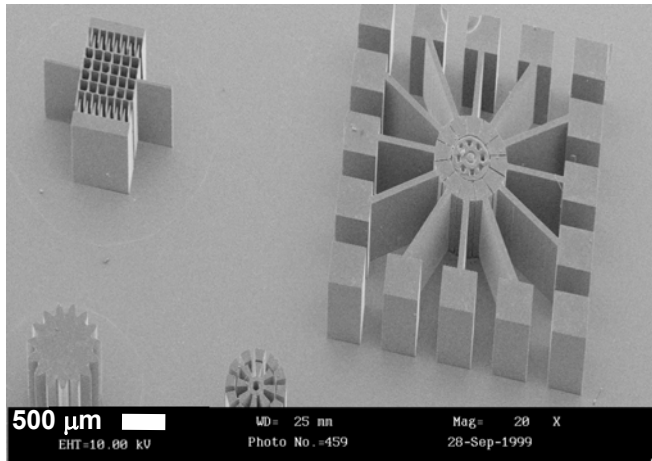
A force ~ 0.1 N exists between a pair of 1mm^2 parallel plates at a separation of 10nm

\sim atmospheric pressure!

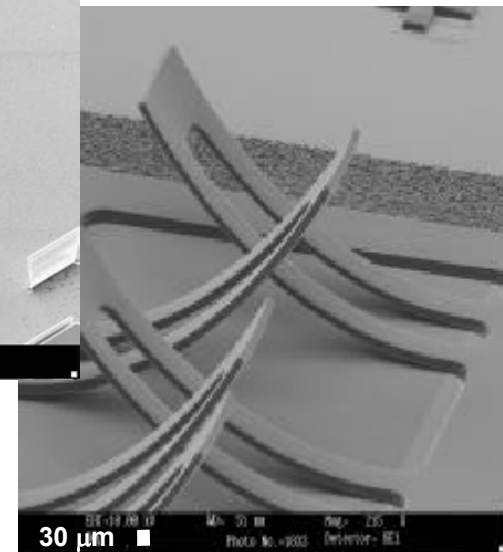
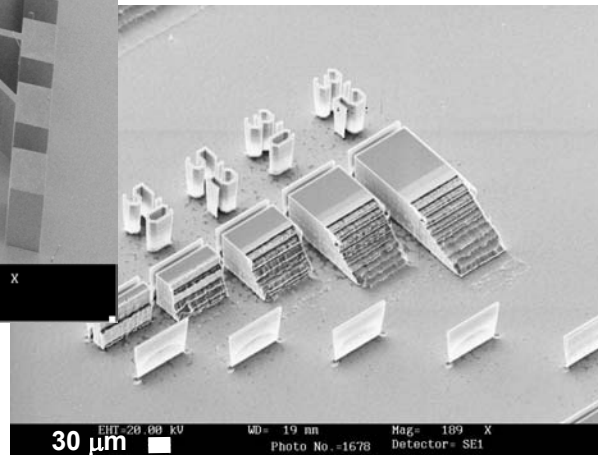


Casimir Force

Influence on MEMS/NEMS structures



- Lower limit to size of M/NEMS structures

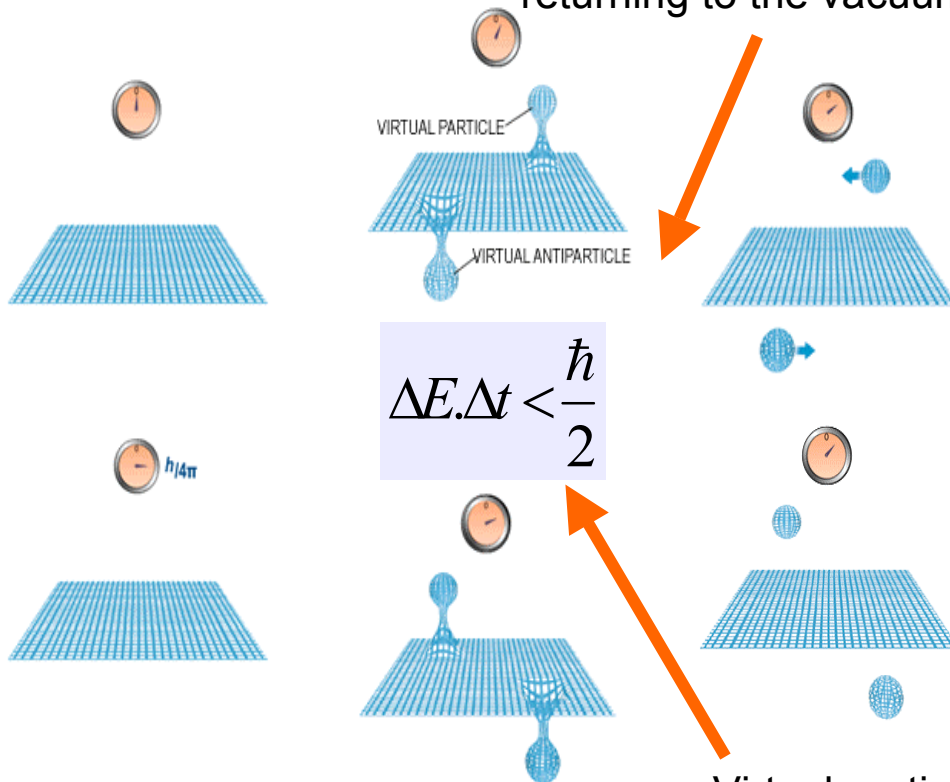


- Potential cause of Stiction
- Potential solution to stiction by using repulsive force through
 - Geometry control
 - Material control

Virtual Particles ... Quantum Foam

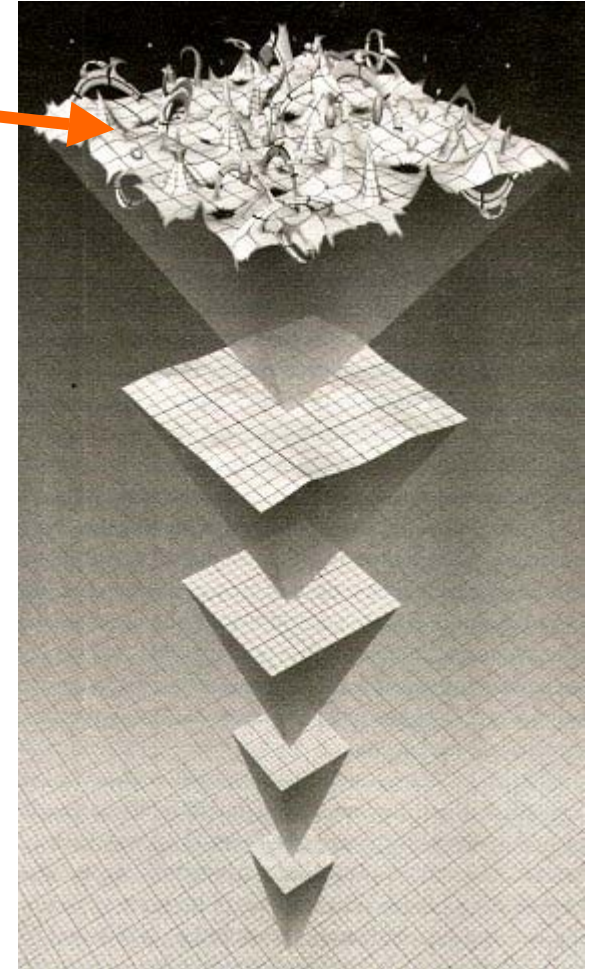
At the Planck scale space time is topologically complex

Characterised by virtual particles springing into existence and then returning to the vacuum.



$$\Delta E \cdot \Delta t < \frac{\hbar}{2}$$

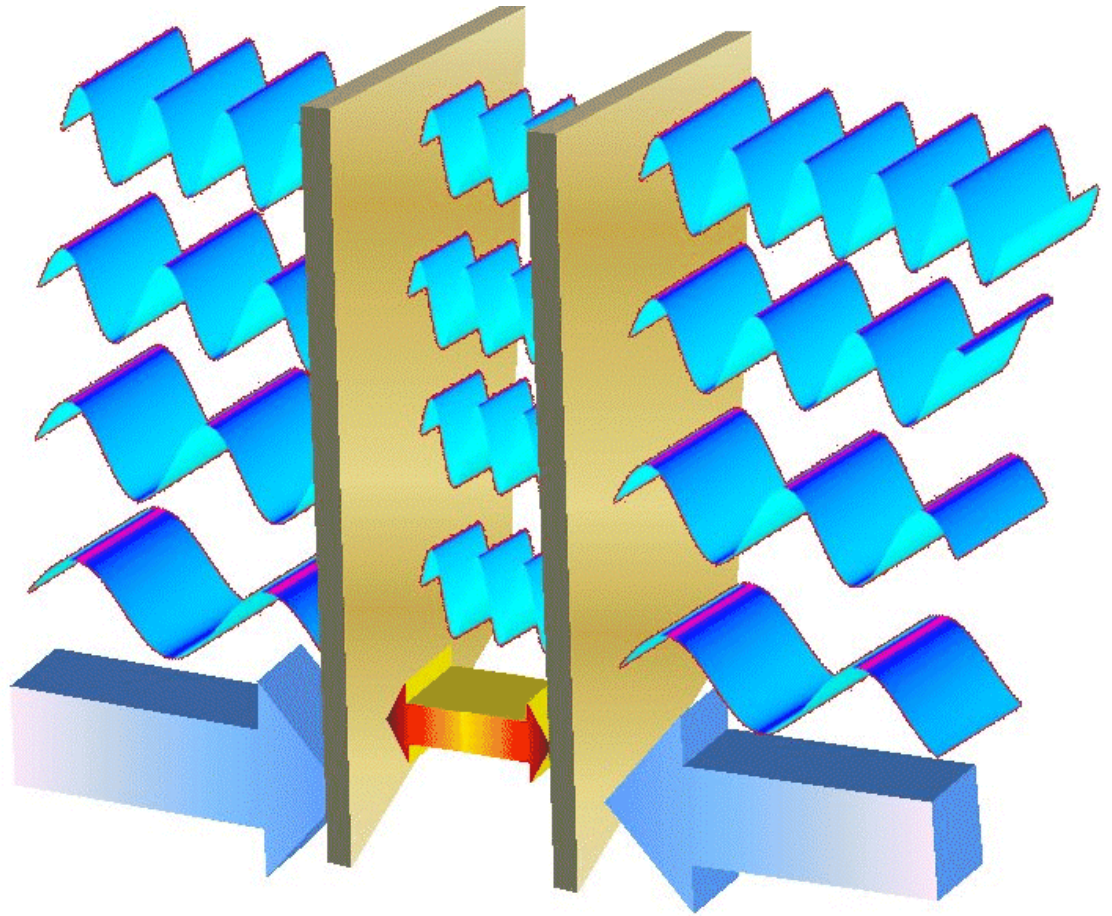
Virtual particle energy and its lifetime are related by Planck's constant



*For a pair of parallel plates
the force is described by:*

$$F = \frac{\pi^2}{240} \frac{\hbar c}{d^4} A$$

*c is the speed of light,
d the plate spacing
and A the plate surface area.*



The Casimir effect seen as resulting from quantum vacuum fluctuations – the plates exclude the longer wavelengths and thereby induce a pressure difference between the internal and external space resulting in a force that pushes the plates together. Put another way the quantum state for a volume of space is different when that volume contains a physical object. This difference causes the Casimir force. Depending on geometry and material properties the force may be either attractive or repulsive

The Casimir force

Analytically calculable for only for a few special cases

More complex cases - Proximity force theorem

quasi-parallel geometries only

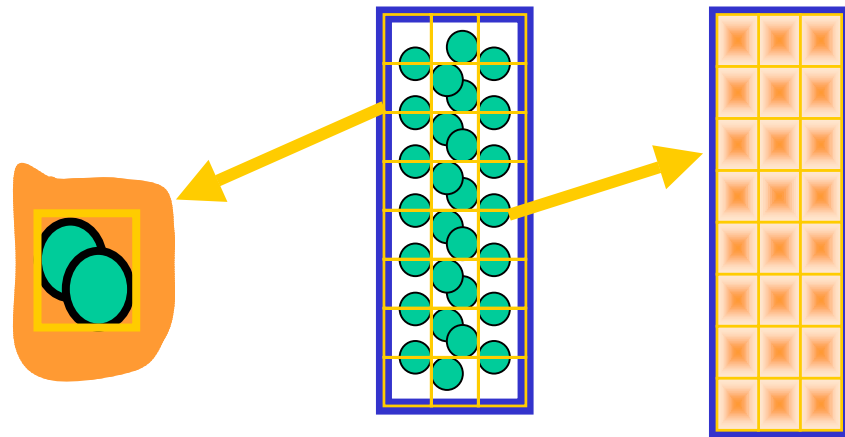
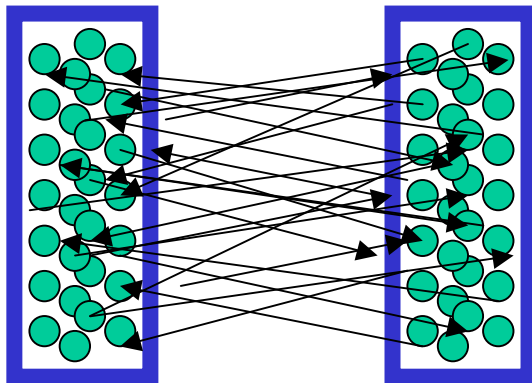
- Lattice QED

complex, slow and incorrect for some configurations

A general tool, applicable to MEMS structures, based on

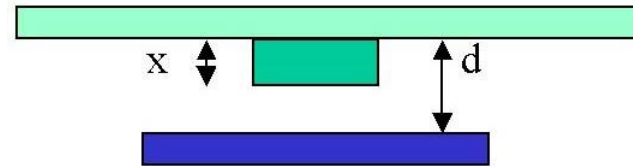
The Additive Principle, has now been developed at RAL under ESA contract.

1. The additive principle

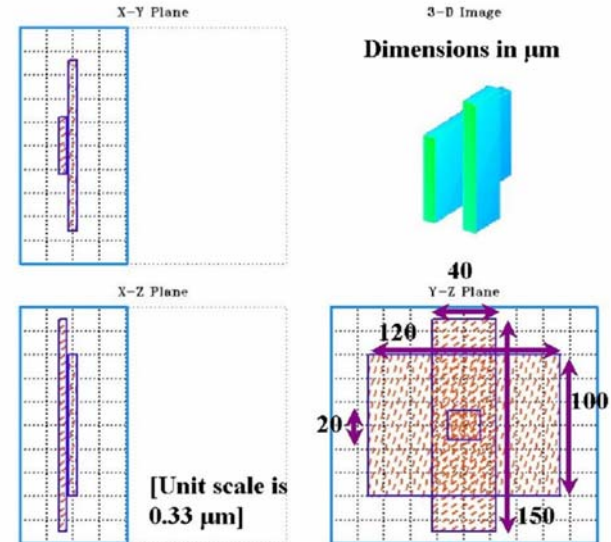


The system to be calculated is divided into an array of matter cells as an atom-by-atom calculation would obviously be impossible.

A Typical Example

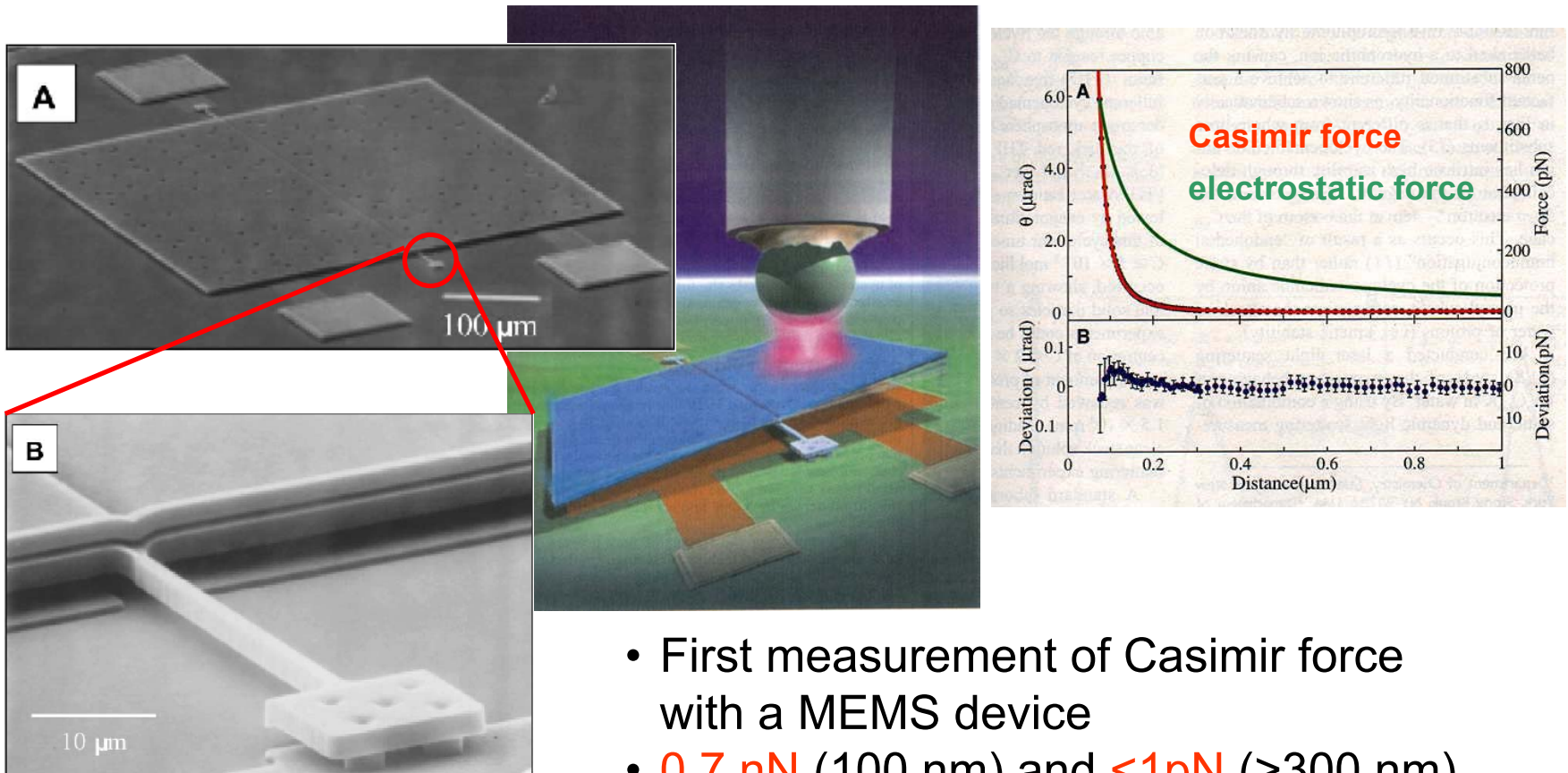


1. Set up geometry in GUI
2. Set up calculation
– ie define range of calculation
3. Calculate Casimir potential
– calculates coarse grid,
and derives adaptive mesh
4. Calculate the force
5. Show visualisation



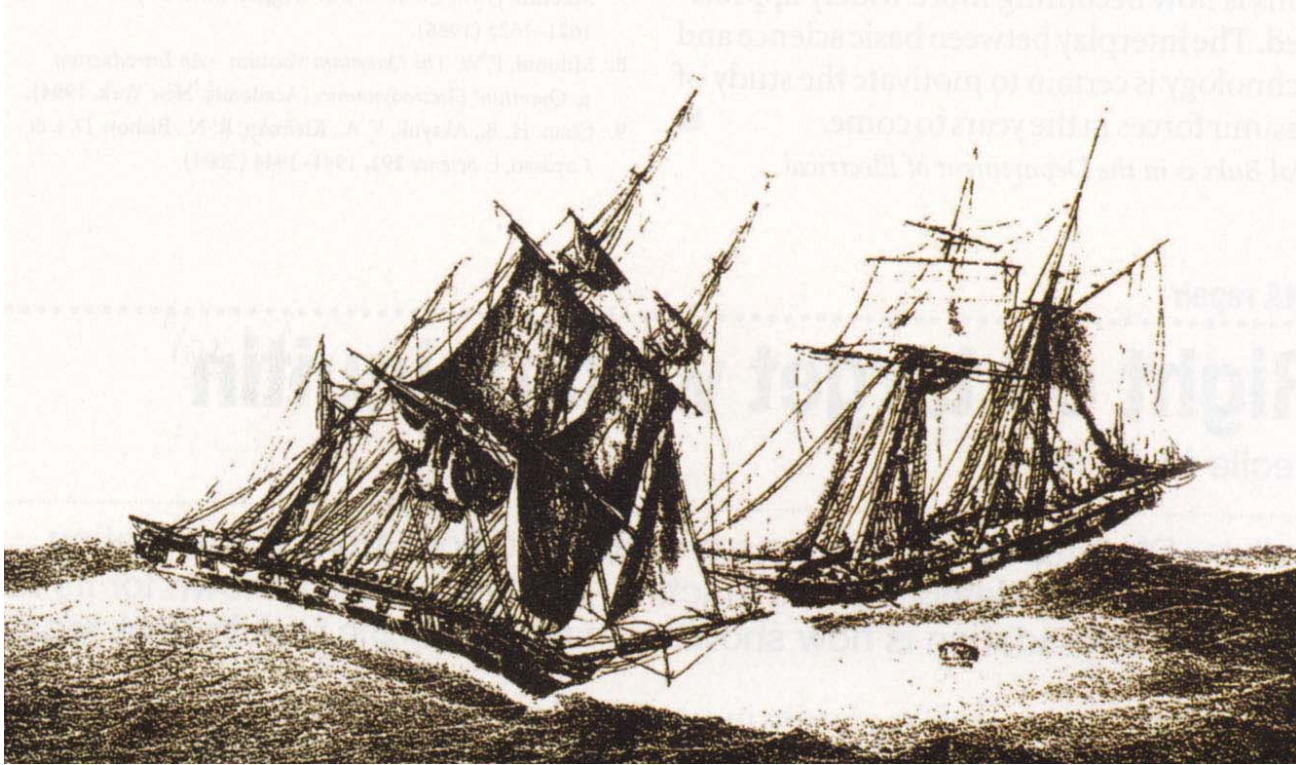
MEMS device to measure Casimir force

by H B Chan *et al.* (Bell Labs, Lucent Technologies)



H B Chan, V A Aksyuk, R N Kleiman, D J Bishop, F Capasso, *Science* **291**, 1941 (2001) and *Physics Today* Oct. 2001 p.43

An early manifestation of Casimir like force



In the days of the great square-riggers, sailors often noticed that under certain conditions, ships lying close together could mysteriously be drawn together – often with grave consequences. [L'Album du Marin (The Mariners Album), 1836, P.C. Caussée]