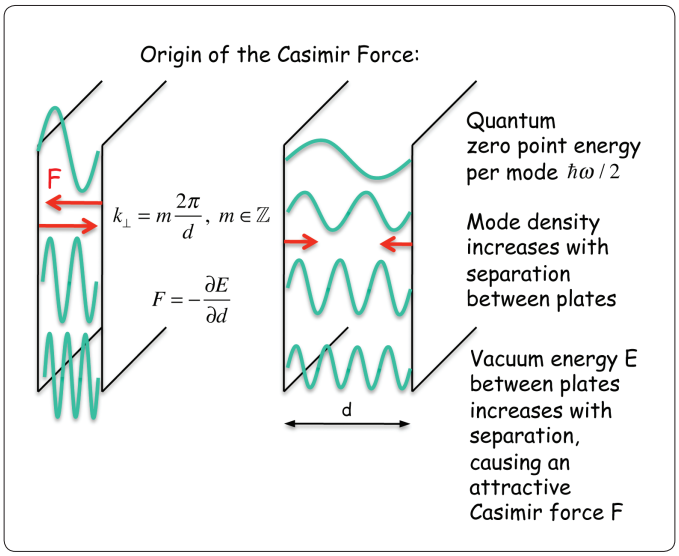
Harnessing the Casimir Effect

BY MARK INGEBRETSEN

IN THE MYSTERIOUS REALM OF QUANTUM MECHANICS, nothing is as it seems. Even a totally dark vacuum has been shown to be teaming with energy of virtually every possible wavelength. Scientists know this because of a phenomenon called the Casimir effect, named after Hendrik Casimir, the Dutch physicist who discovered it in the late 1940s.

More recently, Costas Soukoulis, senior physicist at the Ames Laboratory, along with Ames Lab assistant scientist Thomas Koschny and their colleagues elsewhere, discovered a way to harness the Casimir effect using an exotic class of materials known as chiral metamaterials. The results were published in the Sept. 4, 2009 issue of *Physical Review Letters*, in an article entitled, "Repulsive Casimir Force in Chiral Metamaterials."

The group's work, which could one day make nanoscale machinery operate in a virtually frictionless environment, has already netted considerable interest in the scientific world. During a recent presentation in London, Soukoulis was bombarded with fellow physicists' questions. And for good reason. Besides being the first to suggest that chiral metamaterials were capable of inducing a repulsive Casimir force, the team joins a small group of scientists who've been able to manipulate the elusive force at all.



Casimir theorized that if you placed two objects — plates, for example — close to one another inside a vacuum, the longer wavelengths of the electromagnetic field present even in the vacuum due to Heisenberg's uncertainty principle would be blocked, since they couldn't fit between the small gap separating the plates. The smaller the gap, the fewer modes fit. Thus, the amount of energy density inside the gap decreases as the size of the gap decreases. So work has to be done to pull the plates apart. As a consequence, an attractive force exists that prompts the plates to come closer together.

Soukoulis, who is also a Distinguished Professor of Liberal Arts and Sciences at Iowa State University, and his team wanted to do just the opposite: harness a Casimir force within the gap, capable of pushing the two plates apart. This repulsive Casimir force might have an important practical purpose. Namely, it could be used to overcome something called van der Waals forces that are the bane to engineers. Van der Waals forces – think of them as Casimir waves – are minute. But in nanoscale environments they're strong enough to cause tiny devices to permanently lock up.

Costas Soukoulis

To induce their repulsive force, the researchers turned to chiral metamaterials, artificial substances that can change the characteristics of energy waves when those waves are reflected off them. Some weak chiral materials, such as sugar, can be found in nature, but only artificial metamaterials allow for the much stronger chirality required to obtain a repulsive Casimir force. Whether natural or artificial, chiral materials share a common, albeit somewhat peculiar, trait: their molecular structure is such that they cannot be superimposed on a mirror image of themselves.

Because the chiral materials Soukoulis' team studied were artificial, they could be engineered so that waves reflected off them cause the energy in the gap to decrease when the plates are pulled apart, exerting a repulsive Casimir force within the gap separating the two plates, in contrast to the usually attractive Casimir force. This is made possible due to the additional degree of freedom that crosscouples electric and magnetic fields in chiral materials.

If those plates had instead been the moving parts of a nanomachine coated with chiral metamaterials, the repulsive force generated by the metamaterials theoretically would have neutralized the van der Waals forces, causing the moving parts to operate essentially without friction.

Creating chiral metamaterials is expensive and difficult. So the researchers demonstrated their work via a complex mathematical equation. And while the team isn't sure if the amount of repulsive force they've harnessed is enough to overcome van der Walls forces in nanodevices, they've succeeded in opening a new direction of research that may greatly expand the role of nanotechnology someday, while making the quantum realm a little less mysterious.