A Stern-Gerlach separator of chiral enantiomers based on the Casimir-Polder potential

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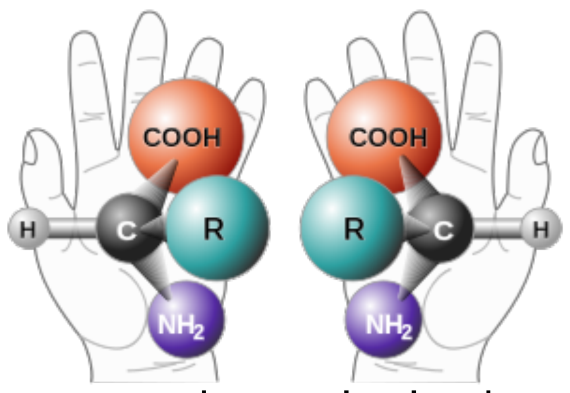
1. Motivation

Many molecules are chiral which can exist in left- and right-handed forms (i.e., non-superimposable mirror images). These two forms of a chiral molecule are known as **enantiomers**.

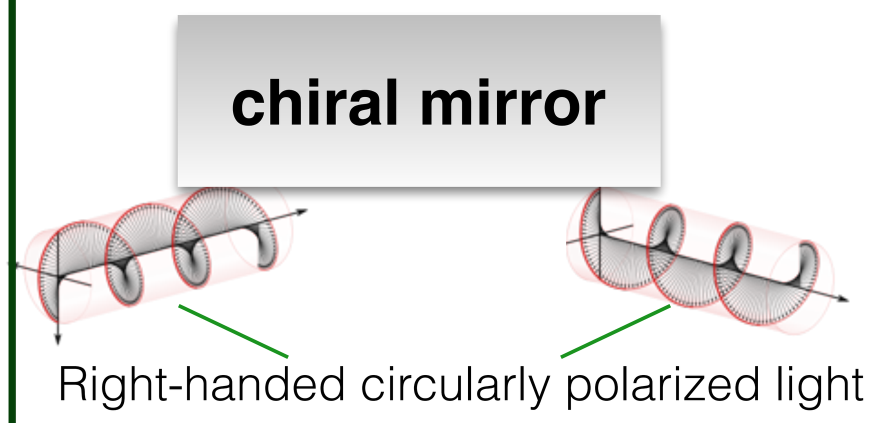


It is important to separate them in industry/ pharmacy to choose the right enantiomer to obtain the desired effects since the other enantiomer is less active, inactive, or can even have high toxicity. We propose a new method for the separation of chiral molecules using the Casimir-Polder force.

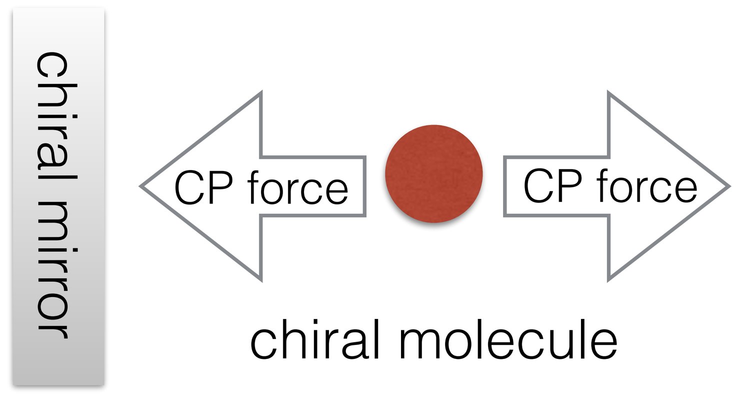
2. Parity violation in Casimir-Polder force

A molecule and a normal mirror **attract** each other by Casimir-Polder force caused by the exchange of photons.

For circularly polarized light, normal mirrors reverse its polarization upon reflection, but the chiral mirrors conserve the polarization.

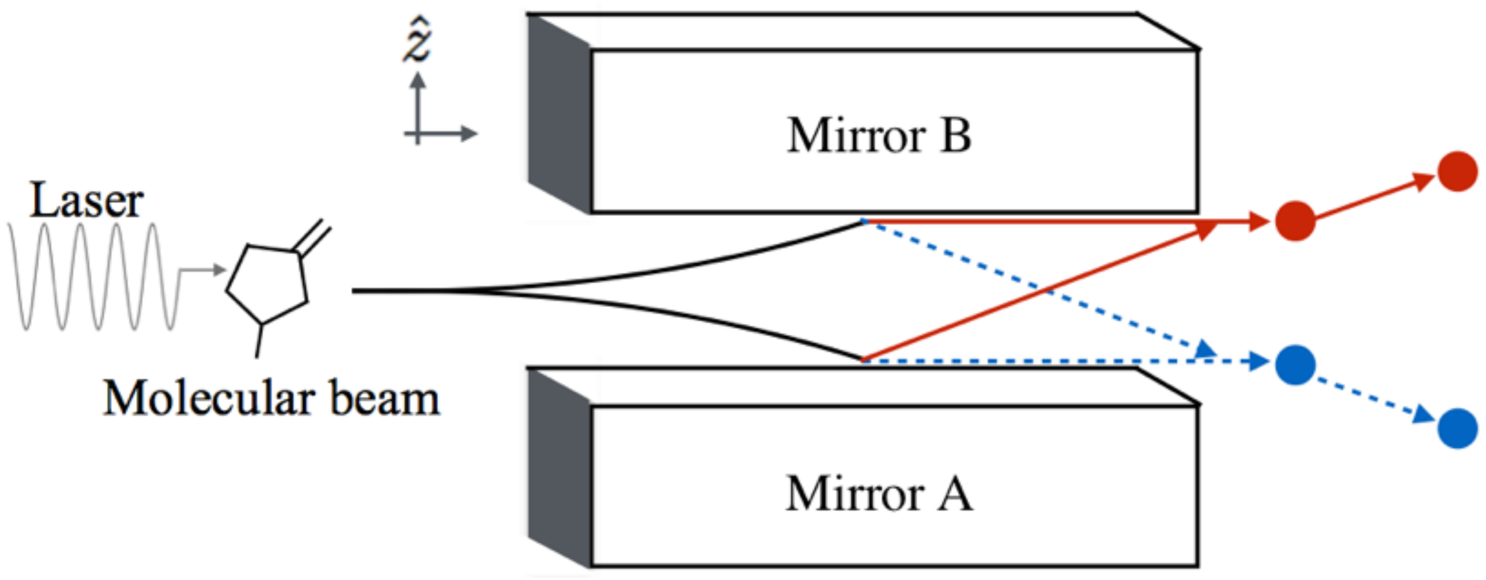


For the Casimir-Polder force between a chiral mirror and a chiral molecule, there exists the chiral dependence of the force which can be **attractive or repulsive** depending on the chirality of the molecule and the mirror.



= Parity-violation of the Casimir-Polder force caused by circular dichroism of a chiral mirror and a chiral molecule.

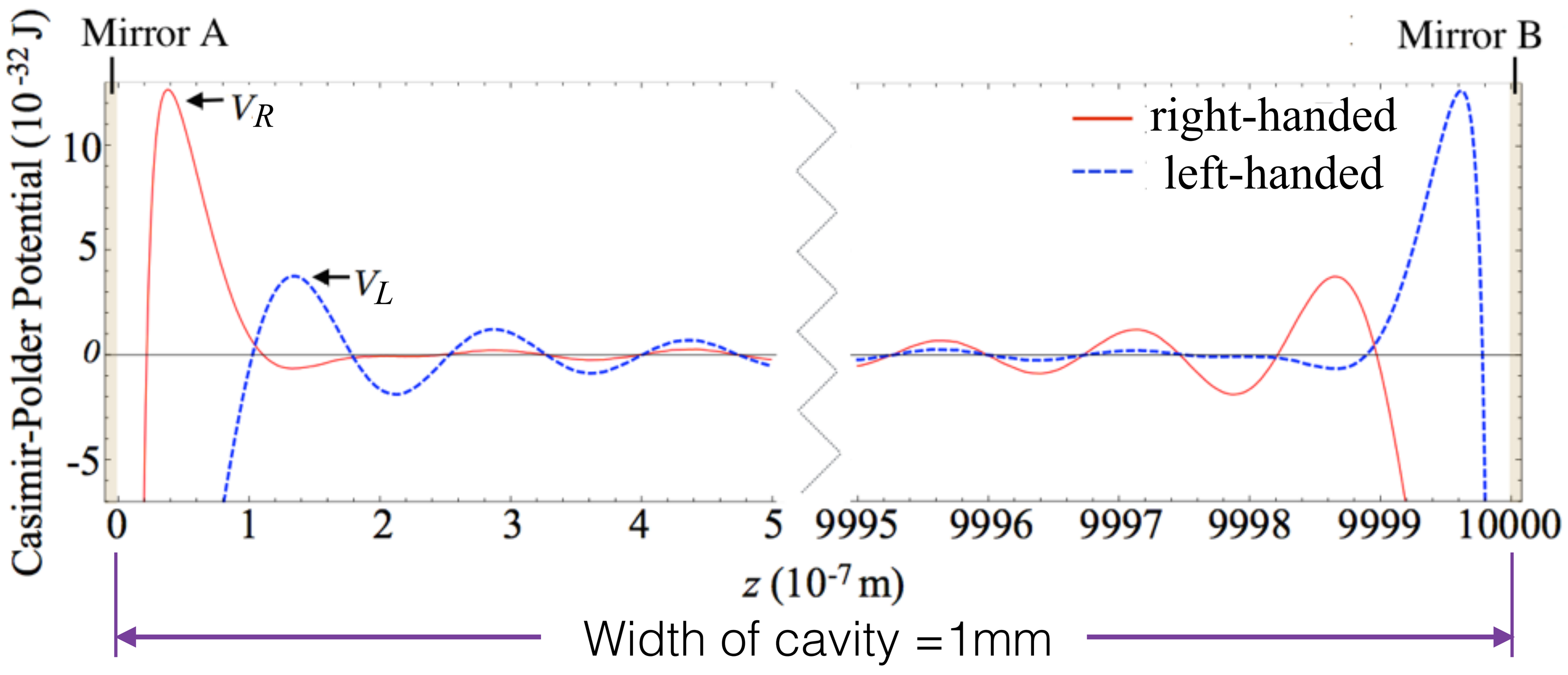
3. Stern-Gerlach type discriminator for enantiomers



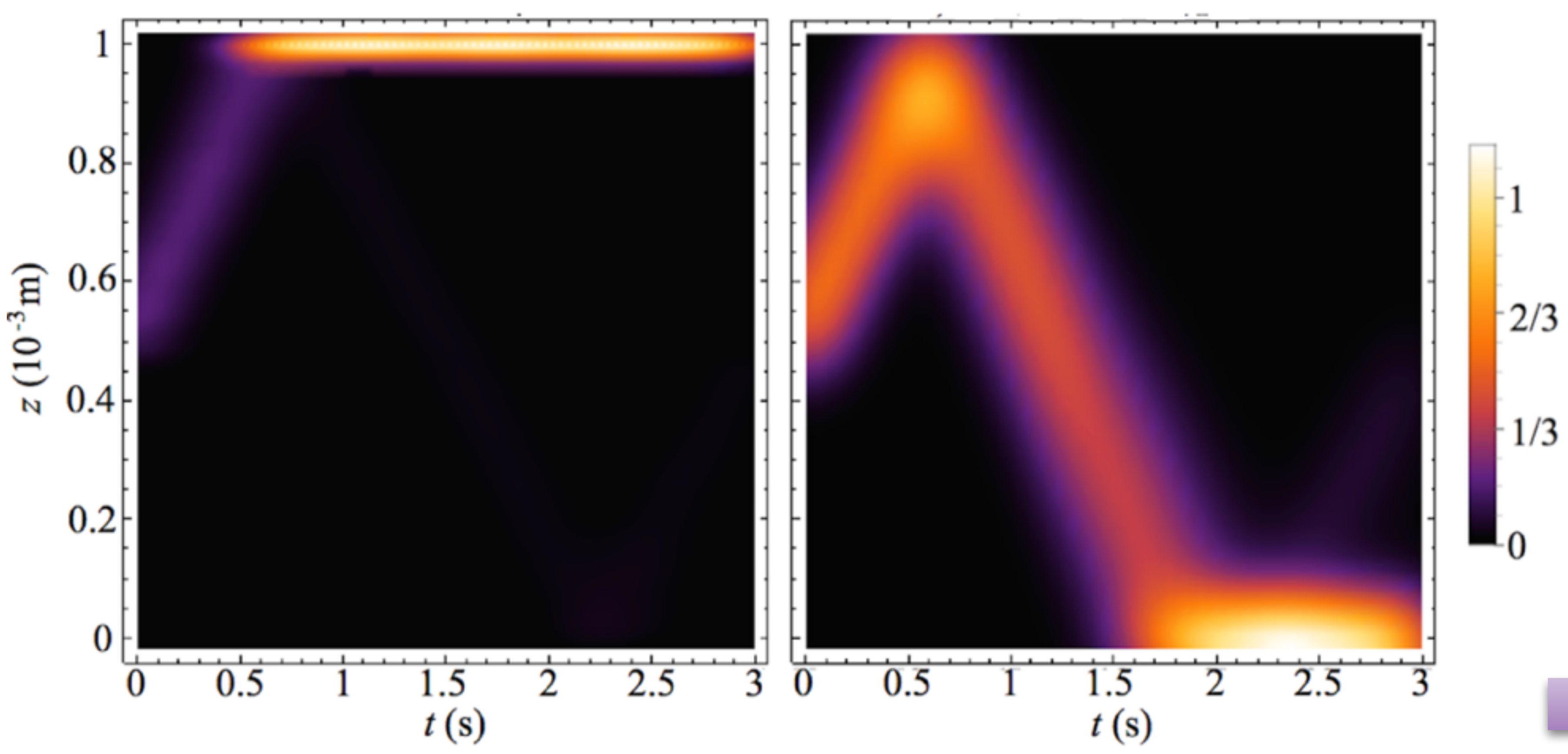
We consider a planar cavity consisting of two chiral mirrors of opposite handedness.
We send 3-methyl-cyclopentanone (3-MCP) molecules (exhibit electric circular dichroism by absorbing left- and right- circularly polarized light differently by electric transitions in the ultraviolet region) into the cavity.

The right-handed molecules see a high potential barrier near mirror A,
while left-handed molecules see a high potential barrier near mirror B.
These differences in potentials seen by right- and left-handed molecules come from chiral dependence of Casimir-Polder potential.

Casimir-Polder potential seen by (right-handed/left-handed) 3-MCP molecules in the cavity



Trajectories of chiral enantiomers in the cavity



Right-handed molecules climbs up the low potential barrier and gets attracted to mirror B, while left-handed molecules can not overcome the high potential barrier and gets repelled back to the opposite side of the cavity.
The opposite behavior of the enantiomers can be observed near mirror A.
In this way, we collect right-handed and left-handed molecules near mirror B and A respectively.

Enantiomers of opposite handedness can be separated around one millimeter after one second due to the parity-violation of the Casimir-Polder force!

4. Conclusion

Conventional methods for enantiomers separation such as chromatography highly depend on the quality and selection of columns used.

Here we propose a more universal method which only makes use of a chiral metamaterial and the parity-violating Casimir-Polder force which it induces.

Our setup also sheds light on the fundamental properties of the Casimir-Polder potential with chiral metamaterials.

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