Search for eEDM in cryogenic crystals

PHYDES: Para-Hydrogen and Diatomic for eEDM Study

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eEDM

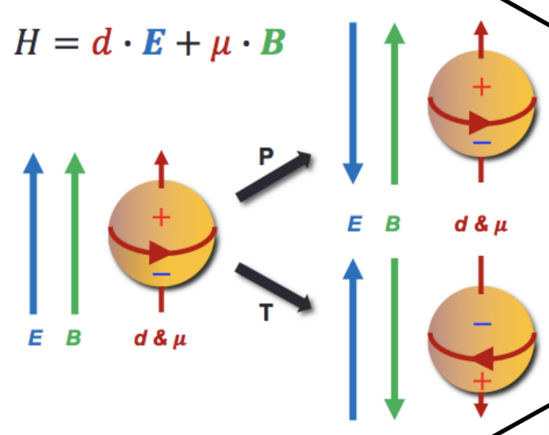
Electron electric dipole moment (eEDM) d_e is the asymmetric charge distribution along the spin direction of the electron.
In the Standard Model (SM), eEDM is zero up to the three loop level and it arises from the CP-violating components of the CKM matrix which is necessary to explain matter-antimatter asymmetry in the Universe. In the SM $d_e<10^{-38}$e·cm, but many extensions predict new contribution to eEDM, making the search of this phenomenon an ideal probe for detecting new physics associated with CP violation.
If we place a free electron in a magnetic field B_0 and electric field E_0, if d_e is non-zero, the interaction with the applied fields makes the spin precess at a frequency given by:

$$\omega_S = \gamma_e B_0 + \frac{d_e}{\hbar} E_0 = \omega_L + \omega_d$$

where the magnitude related to the eEDM can be expressed as:

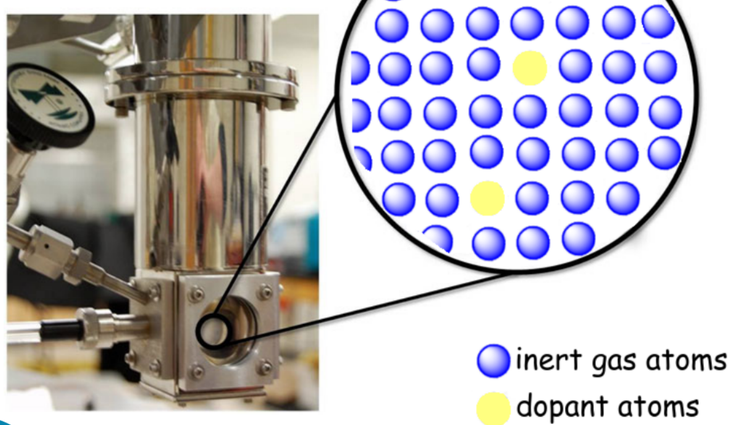
$$\omega_d = 2\pi \times 2.4 \times 10^{-5}\mathrm{Hz} \left(\frac{E}{10^{10}\mathrm{V/cm}}\right)\left(\frac{d_e}{10^{-29}\mathrm{e\,cm}}\right)$$

The actual experimental limit for d_e is 10^{-29}e·cm.

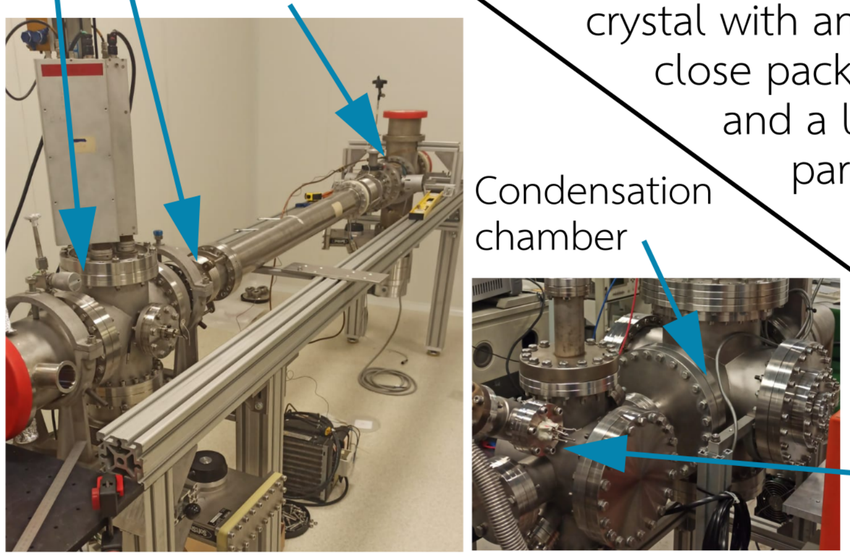


MIT

In the Matrix Isolation Technique (MIT), the guest particles (atoms, molecules or ions) are embedded within a continuous matrix of solid crystal (matrices) made of the inert gases solidified at cryogenic temperatures. This technique is very useful and it presents many advantages:
1) only a feeble interaction between host and guest can take place;

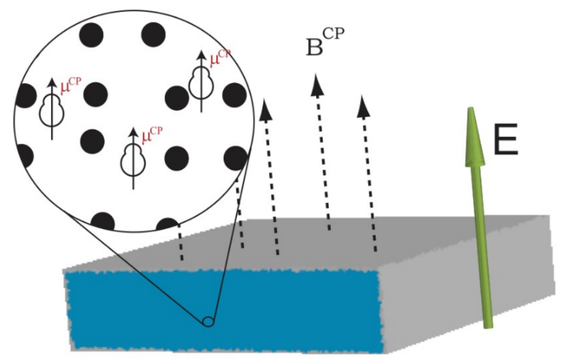


2) since the environment is solid, the diffusion processes of the guest atoms in the matrix are strongly suppressed;
3) a large number of guest atoms can be usually embedded into the solid and thus a higher density of guest particles can be achieved.
Experimentally, the inert gas is mixed with the dopant atoms and sprayed onto the cold surface where it condense and forms a solid layer. In parahydrogen (pH2) the spins of the two hydrogen nuclei are opposed resulting in a low energy configuration. By cooling pH2 below 13.8K, a solid crystal with an hexagonal close packed structure and a lattice parameter of 3.78Å can be obtained.

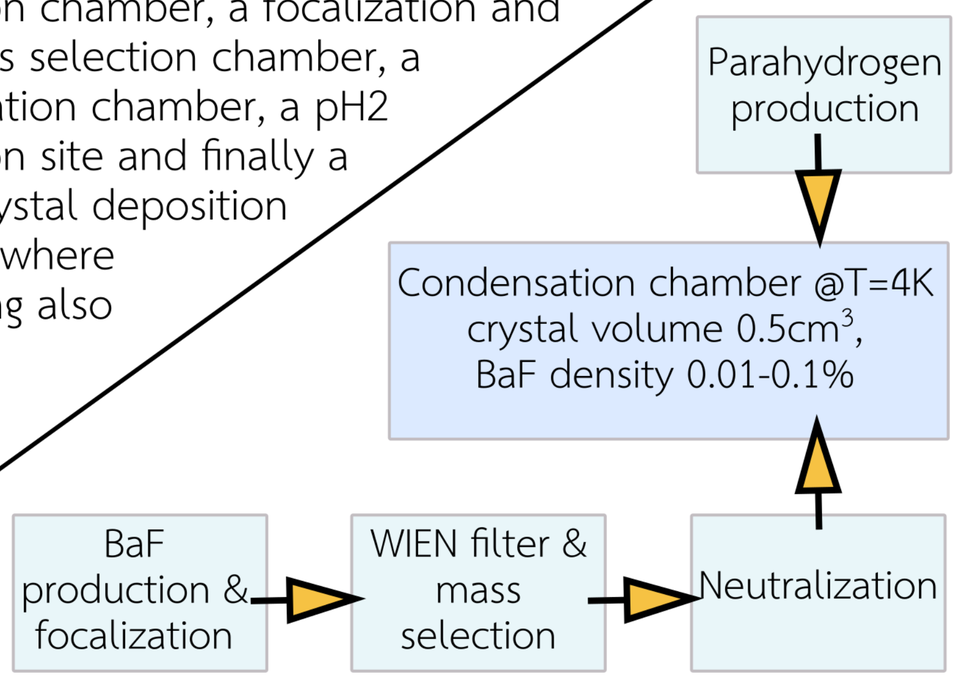


PHYDES

PHYDES is an R&D project funded by INFN V committee.
The idea is to use diatomic polar molecules where eEDM effects are amplified because of the large internal molecular effective field and to embed such molecules in a solid cryogenic matrix. By using the link between eEDM and spin, each molecule will present a thermodynamically averaged magnetic moment μ^{CP} proportional to d_e, oriented along the molecular axis. Applying a polarizing electric field E to the matrix, molecular μ^{CP} becomes oriented and generates ultraweak magnetic field B^{CP}. By measuring B^{CP} one places constraints on eEDM.
The key aspects are:
1) find a molecule with large effective field;
2) maximize the density n;
3) work at low temperature;
4) choice the best host element.



In the PHYDES R&D we will exploit parahydrogen as matrix and BaF molecules to verify the possibility to use this technique to set limits on eEDM. As shown in the scheme, the experimental set up is composed of 5 different parts: a molecular production chamber, a focalization and ionic mass selection chamber, a neutralization chamber, a pH2 production site and finally a doped crystal deposition chamber where performing also tests and measure-ments.



References:
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