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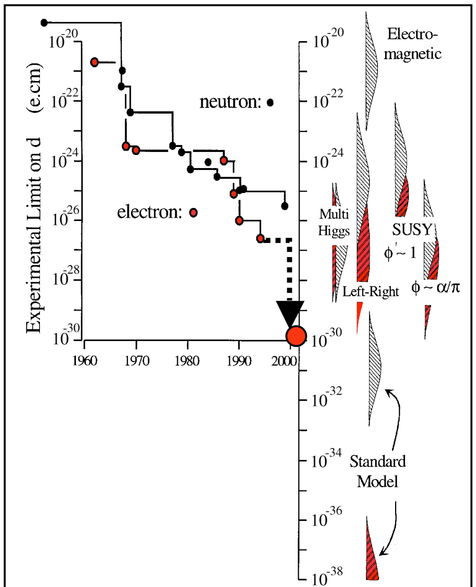
Search for a Permanent Electric Dipole Moment (EDM) of the Electron using a Paramagnetic Crystal

As far as we know, the Standard Model (of elementary particle physics) accounts for all known physical phenomena. In basic-physics research, we design experiments that test these predictions to further refine the models. This search could lead to the discovery of significant physics principles beyond the Standard Model and could help to explain the asymmetry between matter and antimatter in the universe. Well-motivated experiments to search for phenomena that cannot be described by the Standard Model as it is now concieved are therefore crucial to advancing our understanding of nature at its most basic level.



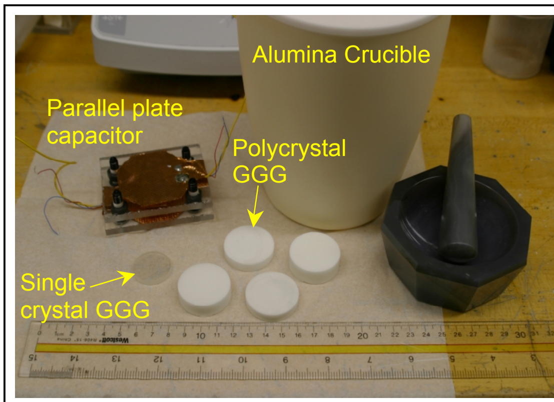
This graph plots the results of experiments searching for the EDM of electrons (red) and neutrons (black). Although neither EDM has been precisely determined, each experiment increases in sensitivity and, therefore, eliminates the possibility of the EDM at that energy level or higher. The chart on the right shows the ranges of energy at which the different theories predict either the eEDM (red bands) or nEDM (gray bands) will occur. As our experiments increase in sensitivity—until we actually measure the eEDM or the nEDM—we eliminate these theories as potential predictors of physical systems.

We are carrying out one such experiment in which we are searching for an intrinsic electron electric dipole moment (eEDM). (EDM sidebar) Theories predict the eEDM to be very small. To date nobody has seen one! Such a moment is forbidden to exist at current observable levels within the Standard Model, at ~10^{-26} e•cm. Our team is preparing to significantly reduce the experimental limit on the size of the eEDM.

That the eEDM hasn't been detected yet has had two effects. First, over 40 years of increasingly sensitive experimentation has steadily reduced the possible size of the EDM of the electron. As a result, the research community is also eliminating potential theoretical models of particle theory as we prove that the EDM must be smaller than those theories allow.

Our experiment draws heavily from ideas elaborated by other researchers. Our experimental design incorporates a solid-state system to measure eEDM. This design was first proposed by Shapiro [1] and implemented by Vasil'ev and Kolycheva [2] in the 1970s, but with indifferent results. With the advent of better superconducting quantum interference device (SQUID) sensors, we can implement this design with much greater sensitivity.

In our eEDM experiment, we will subject a larger (100 cm^3) polycrystal sample (we use gadolinium-gallium-garnet, GGG, as our sample material) to a higher electrical field (10 kV•cm^{-1}) and lower temperature (50 mK) than that in previous experiments. Our experiment has the potential to measure the eEDM with three orders of magnitude greater sensitivity than permitted by previous experimental limits (to the 10^{-30} e•cm range). Such sensitivity will severely challenge supersymmetric theories (unless an eEDM is discovered!).



This photo shows the gadolinium gallium garnet before (single crystal GGG) and after (polycrystal GGG) sample processing. The alumina crucible is used during the heating phases of sample preparation, and the parallel plate capacitor is a part of the experimental apparatus.

We have completed the sample preparation and characterization and have designed and built the experimental apparatus. We will couple the apparatus to our dilution refrigerator in the fall and take our first measurements using the SQUID instruments during the winter. We should have preliminary results by the spring of 2004. By next summer, we intend to field an improved version using optical detection methods.

[1] Shapiro, *Uspekhi Fizicheskikh Nauk*, **95**, 145 (1968).

[2] B. V. Vasil'ev and E. V. Kolycheva, *Soviet Physics JETP*, **47**(2) 243 (1978).