An Electron Electric Dipole Moment Search in the $^3\Delta_1$ Ground State of Tungsten Carbide Molecules

J. Lee and A. E. Leanhardt*
Department of Physics, University of Michigan, Ann Arbor, MI 48109-1040, USA

The Standard Model of particle physics is incomplete. As such, various extensions to the Standard Model, most notably Supersymmetry (SUSY), contain predictions of "new physics" that can be observed by experiments ranging in size from the Large Hadron Collider (LHC) at CERN to laboratory-based, tabletop precision measurements. This talk will focus on the latter, specifically, an electron electric dipole moment (EDM) search using the valence electrons in the $^3\Delta_1$ ground state of tungsten carbide (WC) molecules.

An electron electric dipole moment (EDM) violates both parity (P) and time-reversal (T) symmetries. It is manifest as an energy splitting between spin-up and spin-down states that is proportional to an electric field applied to the electron. This energy splitting, perhaps at the $h \times \mathcal{O}(\text{mHz})$ level or below, must be resolved on top of residual Zeeman shifts that are typically several orders of magnitude larger. We report on progress towards making a continuous tungsten carbide (WC) molecular beam for an electron EDM search [1]. WC has a $^3\Delta_1$ ground state with its two valence electrons in a $\sigma\delta$ molecular orbital configuration [2–4]. This molecular structure has several unique advantages for an electron EDM search and arises in other diatomic species such as HfF^+ [5, 6], ThF^+ [5, 7], and ThO [7, 8]. Our projected sensitivity to detecting an electron EDM reaches across most of the allowed range predicted by Supersymmetric theories.

At present, we have successfully seeded a supersonic gas jet with tungsten carbide molecules formed through the reaction $W + CH_4 \rightarrow WC + 2H_2$ (see Fig. 1). A tungsten filament is resistively heated to ~ 3000 K in the presence of a 95% argon + 5% methane buffer gas. The resulting W and WC vapor is entrained in a supersonic jet formed by allowing the buffer gas to flow through a conical nozzle into vacuum. At low buffer gas pressures, we verify the presence of W and WC in the beam with a quadrupole mass spectrometer [Fig. 1(b,c)]. At high buffer gas pressures, we directly observe the beam profile by allowing the supersonic jet to sputter onto a copper foil placed downstream from a skimmer [Fig. 1(a)]. Future work will focus on optical spectroscopy of the WC molecules entrained in the beam [3].

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* Electronic address: aehardt@umich.edu; URL: http://www.umich.edu/~aehardt/

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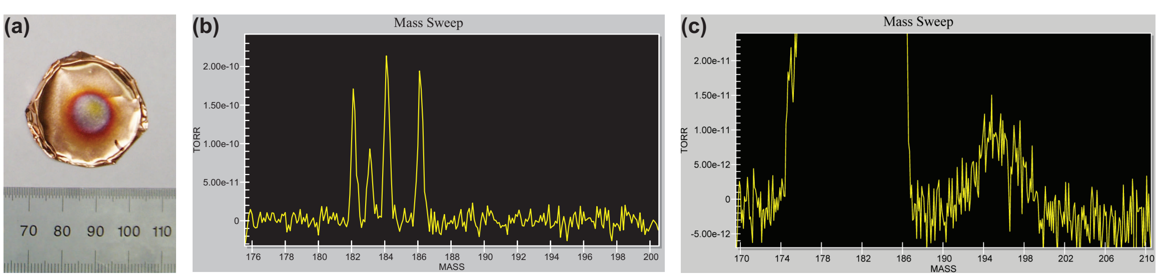

FIG. 1: (a) Tungsten atoms sputtered onto a copper foil placed ~ 25 cm downstream from a 3 mm diameter skimmer. (b) and (c) Quadrupole mass spectra of tungsten atoms (mass 182-186) and tungsten carbide molecules (mass 194-198) formed by evaporating a tungsten filament in the presence of an argon + methane buffer gas.