

# Summary of the workshop “Searching for New Physics with Cold and Controlled Molecules”

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The Workshop took place on 26-30 November 2018 at the Mainz Institute for Theoretical Physics (MITP), Johannes Gutenberg University. Close to 30 scientists from 9+ countries took part in the workshop including several “local” researchers from MITP and Helmholtz Institute Mainz (HIM). Almost half of the participants were students and young scientists. The ratio of theorists and experimentalists was about 2:1.

The idea of this Workshop was to bring together people, who actively work in application of AMO (atomic, molecular, and optical) methods to study fundamental physics. We planned to focus on the remarkable progress that has been recently achieved in control over both internal (electronic, vibrational, spin and rotational) and external (translational) degrees of freedom for a wide range of molecules. In particular, the direct laser and optoelectric cooling of polyatomic molecules has been successfully demonstrated. This opens a way for much higher precision of molecular spectroscopic experiments, which was previously achievable only in atomic spectroscopy.

The molecules in many cases appear to be much more sensitive to “new physics” than atoms. In particular, molecules have higher sensitivity to (i) parity nonconserving interactions (P-odd); (ii) parity and time-reversal invariance nonconserving interactions (P,T-odd); (iii) possible variation of the fundamental constants; and (iv) exotic spin-dependent interactions. All this allows to search for new physics in the previously unreachable domain. An inspiring example is the recent result of the ACME collaboration on the ThO molecule, which placed a new limit on electric dipole moment of the electron  $d_e$  (eEDM) at the level of  $|d_e| < 1.1 \times 10^{-29} e \text{ cm}$ . This limit is more than a hundred times more stringent than the limit following from the best atomic experiment on thallium atoms.

At the workshop, there were several talks describing new calculations of the P,T-odd effects in diatomic molecules, molecular ions, and solids. The size of the eEDM signal depends on the effective electric field  $E_{\text{eff}}$  on the unpaired electrons. Theoretical predictions for the  $E_{\text{eff}}$  were reported for many molecules including all the molecules that are currently used for the eEDM search.

Anatoly Titov presented some approaches used by him and his colleagues for calculations of various molecular properties, including P- and P,T-odd ones. Alexander Petrov reported on a comprehensive theoretical study of the possible systematic effects in the EDM experiments with ThO and HfF<sup>+</sup>. Steven Hoekstra reported recent results of the NL-eEDM collaboration from the ongoing eEDM experiment with a slow BaF beam. Timo Fleig discussed the prospects of breaching the gap between present limit on the eEDM and the value predicted by the Standard model,  $|d_e| \approx 10^{-32} e \text{ cm}$ .

During the workshop, several talks were devoted to the problem of identification of laser-coolable polyatomic molecules, in particular, chiral ones. The latter provide a unique opportunity to measure P-odd interaction in purely spectroscopic experiments. Robert Berger gave an extensive overview of the possible studies of new physics with chiral molecules. Martin Zeppenfeld and Hendrick Bethlem reported progress on cooling polyatomic molecules. An impressive talk by Ronald Fernando Garcia Ruiz from CERN showed a fascinating pic-

ture of experiments with exotic species, including heavy ions and molecules, which include short-lived isotopes with very interesting properties. All in all there were 25 talks (including one Skype presentation by Bhanu Das), all of which were followed by discussions, sometimes rather extensive. As part of the week's program, a joint seminar with JGU QUANTUM was held featuring an inspiring talk presented by Hendrick Bethlem.

An important part of the workshop were presentations from young researchers - MS and PhD students. Konstantin Gaul from the Marburg University presented his research on parity and time-reversal violation in laser-coolable triatomic molecules, Sergey Prosnjak and Daniel Maison from Saint-Petersburg University reported on quantum-electrodynamic effects in heavy-atom systems.

The workshop was organized and sponsored by MITP. All participants were provided with excellent offices, shared with one to three colleagues. According to the common practice of the workshops sponsored by MITP, the schedule was not very dense and allowed for discussions between and after the talks and most of the participants used this opportunity to exchange ideas, establish new collaborations and reinforce the existing ones.

We think we can express the general opinion that such organization proved to be very fruitful, particularly for the young participants. We want to thank Sibylle Wittek, Heidi Stein, and Prof. Dr. Tobias Hurth, the MITP Scientific Coordinator, for the wonderful organization of the Workshop.