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Experimental observation of the vibrational wavefunction of $^4He_2$, $^4He_3$ and $^4He_2{}^3He$ using strong laser-fields

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Synopsis Helium gas is being expanded through a pre-cooled 5 µm nozzle in a supersonic gas jet at low temperatures. Containing small clusters this gas jet passes a transmission diffraction grating, separating clusters of different masses. This mass selected cluster beam is ionized using a Ti:Sa Laser. The Coulomb exploding ionic fragments are measured with the COLTRIMS technique, giving direct access to the square of the vibrational wavefunction of of $^4He_2$, $^4He_3$ and $^4He_2{}^3He$.

Predicted in 1928 by Slater [1], the helium dimer was experimentally first observed more than 60 years later, by Schöllkopf [2] and Luo [3], independently. Before its discovery and even afterwards many theories were published giving different values for the binding energy and with it the bond length.

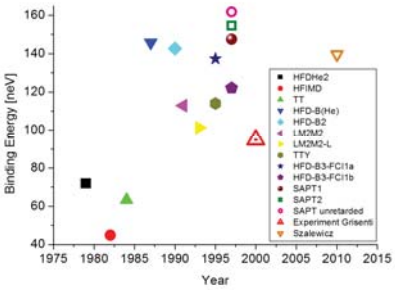

Figure 1. Calculations and measurement of the He dimer binding energy from the last decades.

Being bound only by van-der-Waals forces the He dimer is the largest diatomic molecule in the universe: with a binding energy of only about 100 neV helium dimers are very difficult to produce and only stable at low temperatures. So far Grisenti et al. [4] were able to determine the mean internuclear distance to be 52 Å. Havermeier et al. [5] ionized single helium dimers with synchrotron radiation. Being limited by statistics, these measurements yielded bond lengths of only up to 10 Å.

Separating different clusters, formed in a supersonic gas expansion, with a nano transmission diffraction grating, we were now able to measure the square of the complete vibrational wavefunction using the COLTRIMS technique yielding internuclear distances of up to 400 a.u..

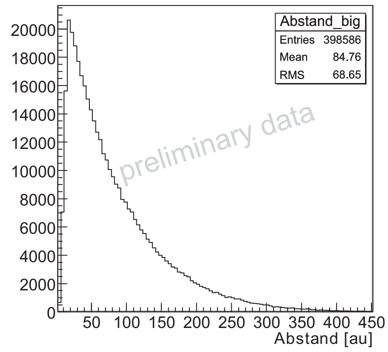

Figure 2. Distribution of the internuclear distance of helium dimers.

In addition we investigated $^4He_3$ and $^4He_2{}^3He$ trimers. Both systems have the same potential and only differ in mass. Furthermore $^4He_3$ is also believed to have a vibrationally excited state with Efimov characteristics [6]. In our experiment the binding energies and the shape of the trimers are measured, clearly revealing the "floppy" character of these weakly bound systems and their difference in shape due to the different masses.

References

[1] J.C. Slater 1928*, Phys. Rev.* 32, 349
[2] W. Schöllkopf *et al* 1994, *Science* 266, 1345
[3] F. Luo *et al* 1992, *J. Chem. Phys.* 98, 3564
[4] Grisenti *et al.* 2000, *PRL* 85, 2284
[5] T. Havermeier *et al* 2010, *PRL.* 104, 133401
[6] V. Efimov 1970, *Physics Letters*, Vol.33B, No.8

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