Direct Detection of Giant Molecules with a Cloud of Cold Ions

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Molecules with a mass above some 10^6 a.m.u. cannot be detected directly today, and there is a strong demand in mass spectrometry to directly detect viruses or antibodies, rather than to rely on fragmentation. We use the passage of a single, charged molecule through a cloud of laser-cooled, radio-frequency trapped ions as a direct detector for any molecule without mass limitation. The crossing of the ion cloud by a charged particle induces a perturbation of the ion cloud's equilibrium state. The temperature variation of the ion cloud is amplified by the radiofrequency heating induced by the confining potential, resulting in the modification of the fluorescence signal of the ion cloud. This fluorescence signal is macroscopic, and can be measured with standard means of non-intrusive photon collection and counting. Every single, charged particle that crosses the ion cloud induces a measurable perturbation of the ion cloud and may thus be detected, independently of its mass. The technology has so far been demonstrated theoretically and numerically [1], and the experimental prototype is delivering first signals.

The experimental set-up combines a versatile molecule source in high vacuum with a linear radiofrequency trap confining a laser-cooled cloud of Ca^+-ions in ultra-high vacuum. The molecular source produces a beam of lowly charged particles with a controlled energy dispersion in order to limit the divergence of the beam throughout the apparatus. Various electrostatic lenses channel these molecules through the trapped ion cloud which is created with a radial extension larger than 100 μm in order to facilitate the interaction with the molecule. Trapping and laser-cooling conditions are tuned so that the perturbation of the cloud and its fluorescence signal are persistent and can be easily detected.

This innovative detector is non-destructive and allows to re-use the molecule for other experiments, it can be coupled to a mass-separation stage (i.e. TOF). This sensor opens a new domain of applications: rapid detection of macromolecules (proteins and viruses for example) in a single step, simply, reliably and unambiguously.

References

[1] C. Champenois, C. Dedonder-Lardeux, C. Jouvet, L. Hilico, M. Knoop, J. Pedregosa, *Non-destructive detection method of charged particles without mass limitation*, European Patent EP14306498 (2014)

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