Charge equilibration times for slow highly charged ions in single layer graphene

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Synopsis We report on charge exchange and energy loss measurements for slow highly charged Xe^{q+} ($q \leqslant 35$) ions after transmission through a single layer of freestanding graphene. Surprisingly short charge equilibration times of only a few femtoseconds are found, which cannot be explained within currently available models.

Highly charged ions can be used as a tool to measure the short-time response of 2D materials to an extremely large, local external field. A charge state of q = 35 implies a local electric field strength of 1.8×10^{11} Vm^{-1} at a distance of 5 Å from it (corresponding to laser power densities of ~10^{17} Wcm^{-2}). Previous work on scattering of HCI from solid surfaces or their transmission through freestanding carbon membranes reported unexpectedly large charge capture within 5 - 30fs [1 and refs. therein].
Recently we took the final step and presented results for the ultimately thin carbon target, a freestanding single layer of graphene [2]. Measurements of the charge state and energy of the transmitted ions surprisingly show that a large number of electrons is extracted from a small surface area (see figure 1).

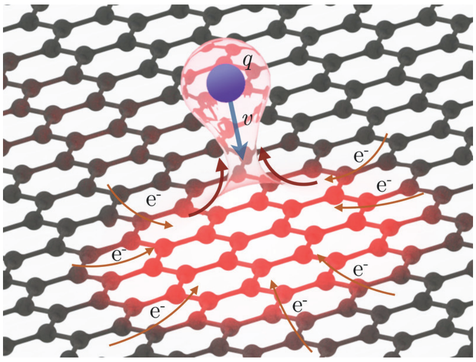

Figure 1. The strong electric field of a highly charged ion is able to capture dozens of electrons from the single layer graphene within a few femtoseconds [2].

Charge equilibration times are derived from the mean exit charge state in dependence of the incident charge state and ion velocity. We find that Xe^{q+} ions equilibrate within a time of only a few fs (see figure 2).

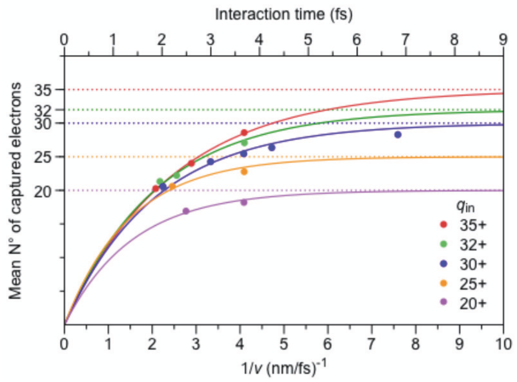

Figure 2. Number of captured (and stabilized) electrons after transmission of highly charged Xe ions (incident charge state q_{in} = 20-35) through a single layer graphene sheet as a function of the inverse projectile velocity [2].

Our current understanding of HCI-solid interaction is not able to explain an almost complete de-excitation of the projectiles within the limited time span of the interaction with a 2D target. This strongly points to a new mechanism, which will be presented at the conference.

References

[1] R.A. Wilhelm *et al.* 2014 *Phys. Rev. Lett.* **112**, 153201
[2] E. Gruber *et al.* 2016 *Nature Comm.* **7**, 13948

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