Deterministic single ion implantation and defect engineering studies using a focused beam of highly charged ions

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Deterministic single ion implantation will be a key to enable novel solid state-based quantum technologies based on e.g., donors in silicon, or NV or other colour centres in diamond, or related materials (Sic, GaN, …). "Deterministic" means, that every single ion arriving at a specific location at the sample during the ion implantation process is counted, which is necessary to fabricate e.g. large scale qubit arrays.
At the Leibniz Joint lab in Leipzig, we have developed a new, worldwide unique deterministic single ion implanter. It was constructed by combining a commercially available focused ion beam (FIB) machine with an electron beam ion source (EBIS), which selectively produces ions of low and high charge states of various species, such as noble gases, hydrogen, nitrogen and soon phosphorous, with nanoscale focus at an acceleration potential of 6 to 15 kV [1].
On the one hand, this setup is used for deterministic single ion detection experiments, employing either the integrated ion beam induced charge (IBIC) system (collaboration with University of Melbourne, Prof. David N. Jamieson et al.) [2,3].
In parallel, a single ion pre-detection scheme based on image charge detection is developed to be implemented in the future [4].
On the other hand, selecting different ion charge states in the ion source enables to conveniently vary the implantation energy from less than 10 up to several hundred keV, which is remarkable using such a compact setup. This is beneficial for systematic defect engineering studies in any material, as we exemplify by direct writing of vacancies in different depths for NV-centre creation in diamond [5].

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