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Penning-trap mass spectrometry using an unbalanced crystal and optical detection

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A novel Penning-trap mass spectrometry technique based on optical detection is under development at the University of Granada. This technique is universal, non-destructive, and single ion-sensitive. The scattered photons by a $^{40}Ca^{+}$ ion will be used to measure the normal mode eigenfrequencies of the unbalanced crystal formed by this ion and a target one [1] when the crystal is cooled to the ground state of motion [2]. The dynamics of the two-ion crystal has been studied, including the quantification of frequency shifts due to the Coulomb repulsion, and a procedure to perform motional quantum metrology has been deduced. Experimentally, the magnetic field of the open-ring Penning trap is the largest ever used in laser-cooling experiments [3], which together with the level structure of the calcium ion has made Doppler cooling challenging.

We have recently demonstrated Doppler cooling of a single $^{40}Ca^{+}$ ion and the crystallization of small ion structures [4]. To achieve this point, a new self-designed optical system has been tested and implemented. Furthermore, improvements on the injection of externally produced ions and on the vacuum system have been introduced. At this moment, we are taking the first steps towards the demonstration of the technique after Doppler cooling on a $^{40}Ca^{+}$ - $^{48}Ca^{+}$ crystal. In this contribution, we will describe the TRAPSENSOR facility, and the results obtained so far. We will end presenting the status on the laser system to perform side-band cooling to reach the ground state of motion in this Penning trap.

[1] M. J. Gutiérrez *et al.*, Phys. Rev. A **100**, 063415 (2019).
[2] J. Cerrillo and D. Rodríguez, EPL- Perspective **134**, 38001 (2021).
[3] M. J. Gutiérrez *et al.*, New J. Phys. **21**, 023023 (2019).
[4] J. Berrocal *et al.*, in preparation.

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