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Sub-microsecond entangling gates between trapped ions via Rydberg interaction

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Trapped Rydberg ions are a novel system for quantum computation and quantum simulation. They combine the key strengths of Rydberg atoms and trapped ion quantum processors in one technology. From Rydberg atoms they inherit the strong dipolar interaction, with trapped ions they share the full quantum information toolbox [1]. This technology has the potential to speed up trapped ion entanglement operations and make them available in large ion crystals. Here, we report on our progress in manipulating the quantum state of trapped Rydberg ions. We have coherently excited trapped ions to Rydberg states [2] and recently we have realized a sub-microsecond entanglement gate between trapped ions via Rydberg interaction [3]. These are important steps towards realizing a fast quantum processor or quantum simulator with trapped Rydberg ions. References: [1] M. Müller, et al., Trapped Rydberg ions: from spin chains to fast quantum gates, *New J. Phys.* 10, 093009 (2008). [2] G. Higgins, et al., Coherent Control of a Single Trapped Rydberg Ion, *Phys. Rev. Lett.* 119, 220501 (2017). [3] C. Zhang, et al., Sub-microsecond entangling gate between trapped ions via Rydberg interaction, arXiv:1908.11284.