Highly dynamic, optical tweezer array for quantum computing

The development of the quantum computing platform based on neutral atoms has made rapid progress in recent years. The approach for this platform is based on the arrangement of optical tweezers (optical tweezer array) and Rydberg gates, whose scalability represents a clear advantage over other concepts. Fraunhofer ILT is developing and building an array of 20 x 100 optical tweezers that allows it to spatially manipulate the qubits in one direction.

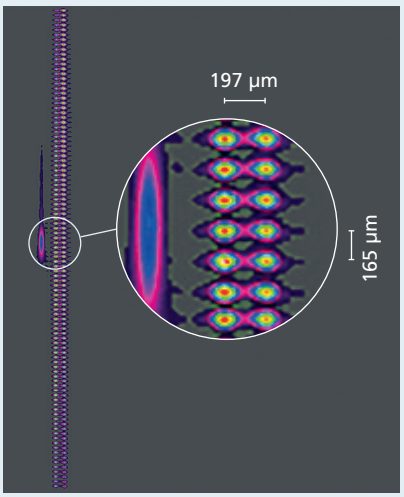
Optics design

Using ray tracing simulations, Fraunhofer ILT has developed an optical system for the project partner University of Stuttgart as part of the BMBF project QRydDemo (www.thequantumlaend.de), in which laser radiation (592 nm) from four single-mode PC fibers is split into 20 channels. Each channel contains an acousto-optical deflector (AOD), which generates a column of 100 partial beams. The 20 columns are spatially merged so that a regular, telecentric arrangement of 2000 laser foci is generated in the intermediate image. This image is reduced by a factor of 50 by a two-stage, telecentric relay optic and imaged into a vacuum chamber. This creates an array with 20 x 100 regularly arranged laser foci with a diameter of 1.2 µm and a distance of 3.5 µm, which is used as an optical tweezer or Rydberg atom trap array. The distances between the laser foci can be varied in the horizontal direction by modulating the AOD control signal on the microsecond time scale, thus realizing highly dynamic qubit connectivity.

Verification of the optical model

Initially, the institute checked the predictions of the optical model on a demonstrator system, which has two columns with 100 laser foci each in the intermediate image. A detailed characterization of the demonstrator system confirmed that properties of the laser foci – such as diameter, distance and telecentricity – were as expected and that the overall system was able to compensate for component tolerances. The superordinate research project QRydDemo is being carried out on behalf of the Federal Ministry of Education and Research BMBF.

Author: Dr. Thomas Westphalen, thomas.westphalen@ilt.fraunhofer.de



1 Laboratory demonstrator for the generation of 2 x 100 laser foci. 2 Measured power density distribution in the intermediate image of the 2-line laboratory demonstrator (line: 200 µm).