Quantum information technology will one day tear down the speed barriers that limit our understanding of complex quantum systems. At its core lies the deterministic and robust generation of entanglement. Our group has succeeded in generating multiparticle entangled states of trapped atoms for the first time, by spin-squeezing a two-component Bose-Einstein condensate of $^{87}$Rb atoms.\(^1\) A full state tomography allows for the reconstruction of the Wigner function of the squeezed states. Such entangled states are immediately useful for quantum metrology, as they open the possibility of overcoming the standard quantum limit of interferometric measurements.

Our experiments take place on atom chips, which provide a versatile and reliable laboratory for quantum-mechanical experiments with ultracold atoms. The next generation of atom chips calls for a dramatic increase in the complexity of the spatially structured electromagnetic fields required for trapping and manipulating these atoms. We have developed a general and reliable tool\(^2\) for designing the best possible electromagnetic chip surface structures which will generate the desired electromagnetic field topology. This will allow atom-chip based quantum technology to be extended to arrays of microtraps with state-dependent potentials, opening the way to constructing quantum processors and quantum simulators through interacting ultracold atoms.

References: