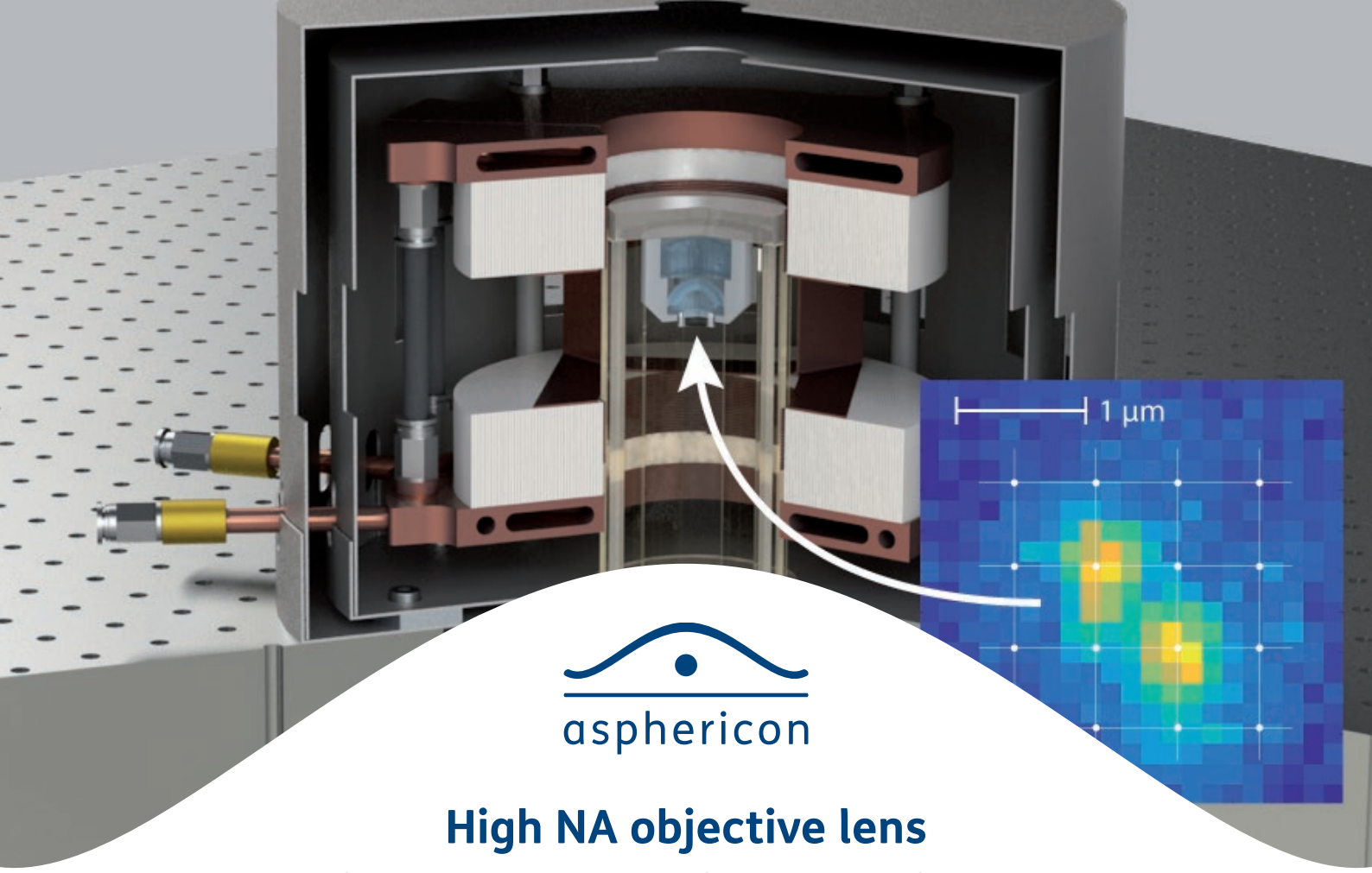



asphericon

# High NA objective lens

## Single atom fluorescence microscope for quantum information processing

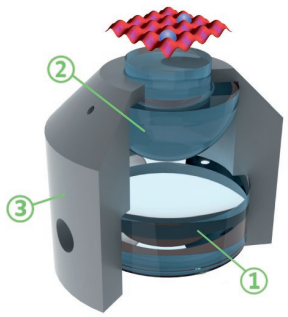
**Project description:**

The Institute of Applied Physics, University of Bonn, is experimenting on imaging and optically controlling ultra-cold cesium atoms trapped in an optical lattice with an unprecedented spatial resolution. To fully resolve each individual atom, which are separated in the lattice by 500 nm, the scientists need a high numerical aperture (NA) objective lens. High NA imaging systems are characterized by a short working distance <1mm. Hence, the objective lens should be able to operate directly in the ultrahigh (~ $10^{\wedge-11}$ mbar) vacuum, where atoms are trapped and manipulated with laser beams. Due to the vacuum requirements (e.g. temperature, outgassing rates) no system was available on the market so far. The scientists have therefore designed and characterized a unique two-lens system, with a nominal NA of 0.92. After a thorough tolerance analysis all deviations were chosen to exceed manufacturing tolerances by at least one order of magnitude.

**Project implementation:**

Both lenses, made of N-SF10, were manufactured by asphericon GmbH and mounted in a ceramic ($Al_2O_3$) holder. An effective characterization of the optical performance was carried out by measuring the point spread function. Due to the high NA of the objective lens this was done by using circular polarized light emitted from an aluminum-coated tapered optical fiber tip with a tip diameter as small as 100 nm. Using this method, it was demonstrated that the performance of the objective lens at full NA is diffraction limited (Strehl ratio > 0.8).

### Objective lens construction




Objective lens consisting of:

(1) an asphere with Ø 25 mm and

(2) one sphere with Ø 20 mm and

(3) a ceramic mounting.

Fig. 1 Two-lens high NA objective lens compatible ultrahigh vacuum environment

### Characterization set-up

The light emitted by a SNOM fiber tip is collimated by the high NA objective lens and focused onto a CCD camera.

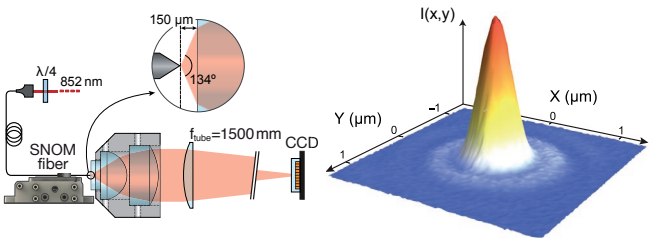



Fig. 2 Set-up for measurement of point spread function

Picture above: Experimental set-up to control the quantum state of individual cesium atoms trapped in an optical lattice

Image and text reference: C. Robens, S. Brakhane, W. Alt, F. Kleißler, D. Meschede, G. Moon, G. Ramola, A. Alberti: „High numerical aperture (NA = 0.92) objective lens for imaging and addressing of cold atoms“, In: Optics Letters, Vol. 42 (2017), Issue 6, pp. 1043-1046

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