D2.5 Evaluation of a quantum interface of light with an atomic ensemble in microstructures cells and characterization

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For our experiment on single photon generation we use a Rubidium vapor cell heated to 100 to 200°C and perform a four wave mixing scheme in the regime of Rydberg blockade to produce single photons. For this scheme we excite the atoms via an off resonant two photon transition to the Rydberg state nS, for n around 40, the intermediate state 5P1/2 with a detuning on the order of 1 GHz and pulsed laser to couple the intermediate state to the Rydberg state with a pulse length of ~4 ns. the third laser for the FWM scheme is coupling the Rydberg state to the state 5P3/2. (see also WP1 report)

One of the technical problems on the way to the single photon source is to address exactly one of the blocked volumes and therefore only one excitation. In a thermal ensemble the length scale of such a volume is about 1 µm which is given by the thermal motion, the bandwidth of the excitation laser and the interaction strength.

After analyzing the feasibility of several methods, like encasing the atoms by a glass cells or limiting the excitation volume by electric or magnetic fields, we concluded that the most promising approach is to focus the first excitation laser with, a wavelength of 795 nm, down to a radius below 1µm.

To do so we analyzed theoretically and experimentally different optical designs based on GRIN (GRadient INdex) lenses placed inside of the cell to produce the focal spot and to collect afterwards the single photons. These lenses have a high NA and arbitrary small working distance, which could be chosen to be as small as possible to avoid any re-absorption. Nevertheless, the tests have shown that these lenses cannot stand the required temperatures above 200°C, which might not be an issue when working with Cesium vapors. Focusing the laser from the outside of the cell gives more freedom in alignment and lenses are replaceable. To do so we first made a survey on glass corrected microscope objectives, which are commercially available. These objectives are usually made for achromatic applications and the assembly of many lenses results in a reduced optical transmission. A solution might be a custom made monochromatic objective, which was discarded for being too expensive.

Finally we decided to use commercial aspheric lenses corrected for 1.2 mm glass (GELTECH 352080). First test have shown a focus of 0.6 µm 1/e^2 radius and a rayleigh length of less than 2 µm, measured with a 0.5 µm diameter pinhole. To reduce thermal expansion of the holder a special design has been done combining INVAR and MACOR ceramics, which can be included in a thermal isolation of an oven heating the cell.

Fig1:We developed a special design for the aspheric lens holder, based on ceramics and Invar. With this holder design we will be able to maintain the optical alignment in the presence of thermal expansion compared to a setup based on traditional opto-mechanics.

We have tested the imaging quality of these aspheric lenses with and without a 1.2mm glass plate.

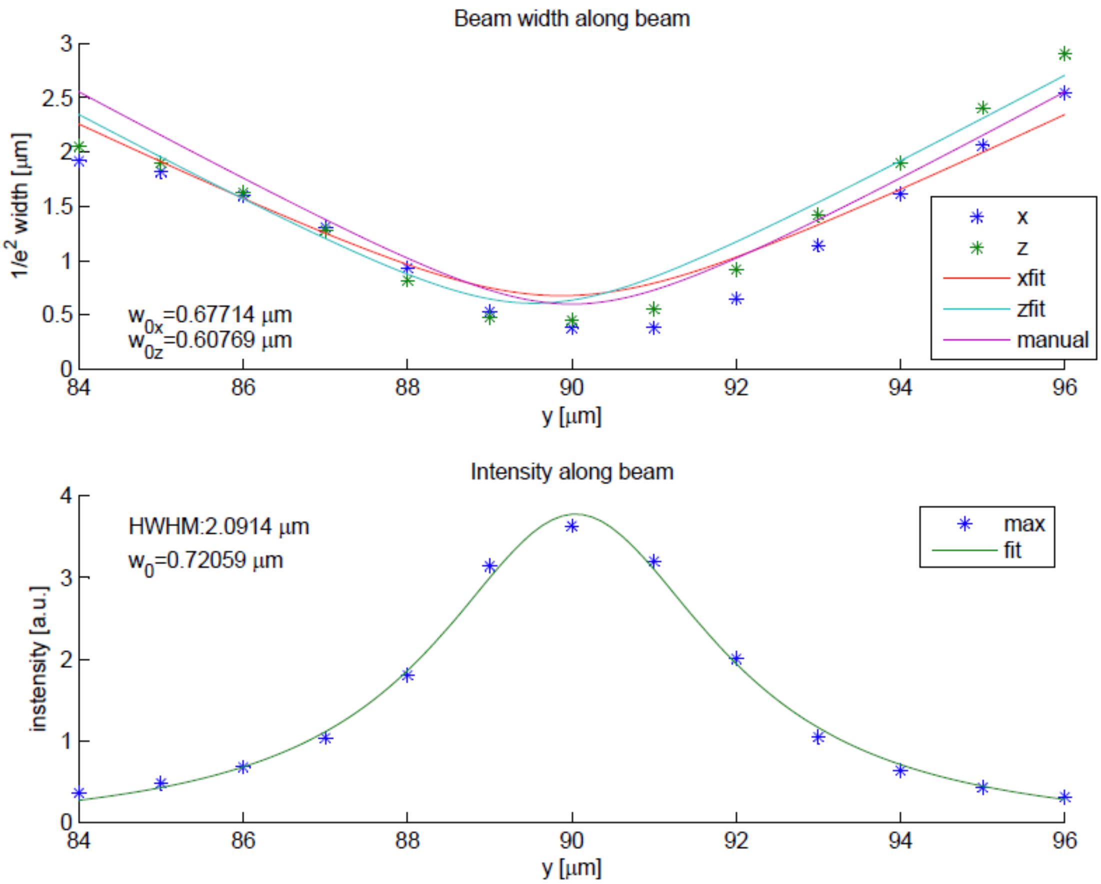

Fig2: Measured beam parameters (with 1.2mm plate) as a function of position. With this setup we are able to reach radially beam of roughly 1 micron and longitudinal Rayleigh ranges of 2 microns. Due to the non-linearity of the 4WM with the intensity in the focal spot, we can actually reach even a smaller effective Volume than just given by the available numerical apertures.