Planar waveguides acting as cavities for x-rays recently paved the way to transfer quantum optical concepts into the regime of hard x-rays [1-4]. The controlled placement of ensembles of Mössbauer nuclei as emitters in the cavity allowed for a precise tuning of the collective light-matter interaction. A crucial aspect is that the cavity geometry allows for the excitation of cooperative radiative eigenstates of the embedded nuclei. This facilitated the observation of the collective Lamb shift [1], electromagnetically induced transparency with nuclei [2] (see Fig.1) and spontaneously generated coherences [3]. Thus, x-ray cavities can now be considered as new laboratory to explore fundamental aspects of controlling the light-matter interaction at x-ray energies [4].

In this contribution I will review the foundations of x-ray cavities including preparational aspects and optical principles that constitute the basis for optimizing their performance. After reviewing recent experimental examples I will give an outlook on future experiments with x-ray cavities. This includes controlling the lineshape via Fano interference and the investigation of the collective strong coupling limit in the formation of nuclear polaritons.

Moreover, x-ray cavities with embedded Mössbauer nuclei can be employed as ultranarrow bandpass filters for x-rays. An interesting application will be the study of magnetic ordering and quantum phase transitions at mK temperatures. Due to the narrow bandwidth, x-ray beam heating of the sample can be avoided, while keeping a high signal with almost no background.

References