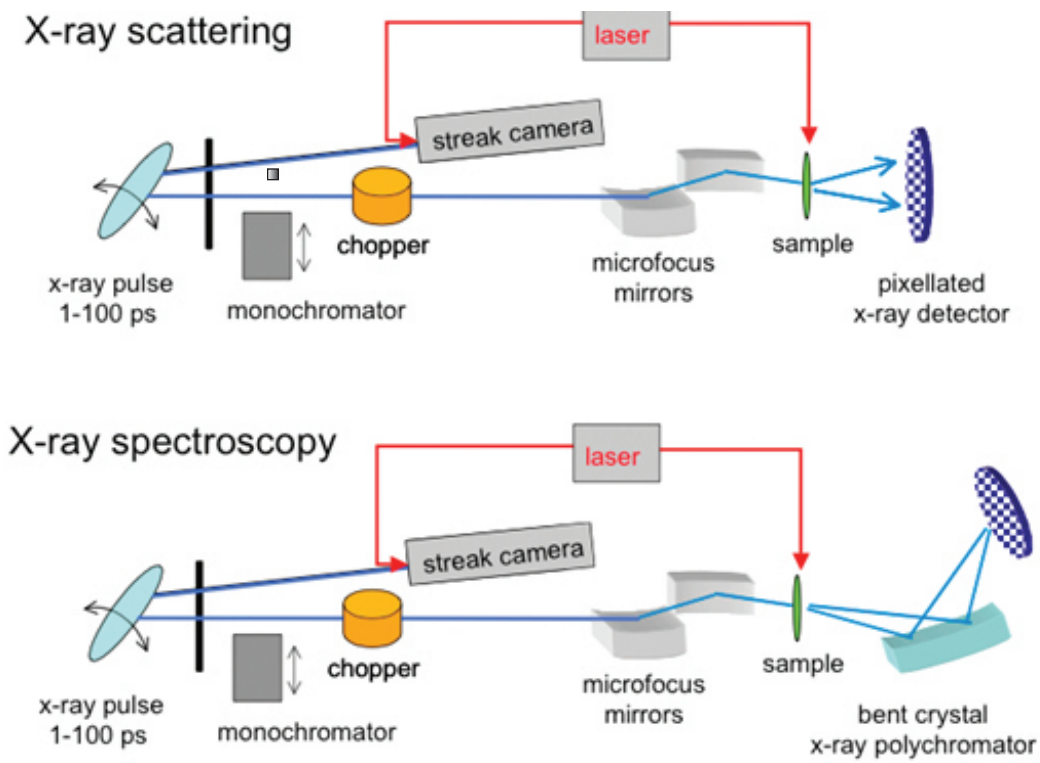
4.3 ULTRAFAST DYNAMICS BEAMLINES

SPX BEAMLINES

The crab cavity scheme (sections 3.5 and 6.1), offers a unique tunable high average flux source of ~1ps x-rays. We propose to develop two beamlines that would be fed by the SPX pulse slicing scheme. R&D on the SPX source (described in 6.1) is required before beginning its construction. Beamline designs have been considered. High-power lasers for pump-probe experiments using accurate sub-ps time synchronization are being developed as extensions of our existing ultrafast science programs and through collaborations with LCLS. The schematic in fig. 4.3.1 displays beamline configurations for scattering and spectroscopy.

Schematic of short-pulse x-ray beamlines

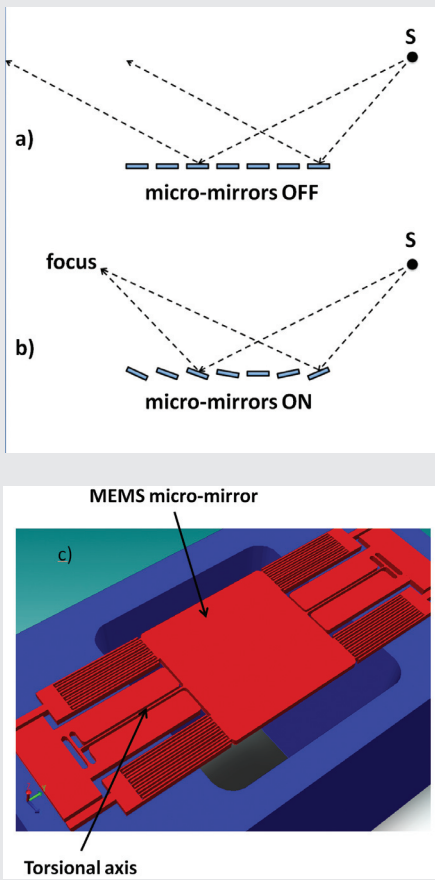
Fig. 4.3.1. *The source for these beamlines is the crab cavity slicing source described in section 3.5.*



We anticipate that we will have two insertion device beamlines and one bending magnet beamline that will have access to the chirped source. With two sectors the intervening bending magnet beamline can be instrumented for ultrafast experiments where brilliance is less important than flux. We anticipate that to satisfy the science needs described in Section 2.3, the undulators for the two ID beamlines will be chosen so that one beamline is optimized for higher-energy, and one for lower-energy experiments. During the R&D phase for the SPX source, we will develop detailed designs and work with users from the ultrafast community to accommodate high-impact experiments.

Micromirrors for adaptive optics and fast switching

Fig. 4.3.2. *The 1-D array of micromirrors shown (a and b) would be fabricated by MEMS technology. As an adaptive optic it could be used for dynamic optimization of the point-spread function. However, it also offers the potential of ultrafast switching of an x-ray beam. Image c) shows a finite element analysis of an individual micromirror.*



INSTRUMENTS FOR ULTRAFAST SCIENCE

High-performance lasers are key to pump probe experiments. We plan to take advantage of improvements in high rep-rate high power laser technology. In the detector program (section 5.1) we plan to develop a suite of ultrafast detectors for imaging and spectroscopy. Several beamlines at APS are already involved in ultrafast experiments or expect to move in that direction. Those experiments that do not require less than 100-ps time resolution are better suited to avoid the SPX sectors because the flux is attenuated by the pulse slicing. Streak cameras and other approaches can be used to reach below 100-ps time resolution. An innovative optics approach with potential for ultrafast studies is shown in fig. 4.3.2.

The APS is well-suited for ultrafast imaging studies on non-SPX beamlines, especially the planned new imaging beamlines (Section 2.1). Attractions include the flexible timing modes which allow for high-speed imaging ranging from 100 ps single exposures to MHz video rates, the wide energy range (10-100 keV) allowing for the study of soft (e.g. water) as well as hard (e.g. stainless steel) materials, and the large number of photons per pulse. There are many areas in science where ultrafast imaging by existing users has provided unique insights, both fundamental and applied, such as free surface flow singularities including droplets merging, pinch-off, and impact on liquids/solids, and the industrially-important process of liquid jet atomization.

Despite our state of the art detection schemes, we are limited to a detective signal to noise ratio of about 12 when using the 100 ps pulse without sample in the beam. The proposed upgrade to the accelerator systems, such as higher electron beam current, and specialized high-brilliance long insertion devices will provide 5 fold improvement in the S/N. Added to the wider field of view afforded by a long dedicated beamline, this will gain us access to more realistic sample sizes and materials of interest as mentioned above. Most importantly the proposed upgrade promises to deliver single-pulse, single-shot imaging using all the x-ray pulses in the standard 24-bunch mode, which translates into MHz frame rate for real-time dynamics studies of non-repeatable transient phenomena such as catastrophic transformations (materials failure, explosions, and rapid chemical reactions). Detector developments summarized in sections 5.1 and 6.4 will be very important. The resulting unprecedented capabilities will put the APS at the forefront of high-speed imaging.