6.1 SHORT-PULSE X-RAY SOURCE DEVELOPMENT

To achieve some of the ultrafast science goals outlined earlier in this proposal, we are pursuing the development of a source of short x-ray pulses with deflecting cavities using superconducting rf (SRF) technology. SRF technology has several key advantages over the conventional normal-conducting room-temperature copper cavities; for example, it enables the cavities to operate at high-rf repetition rates, including continuous wave. This capability, in turn, allows "chirping" not only in the hybrid mode (the only possibility if room-temperature cavities are employed), but also in all operating modes of the storage ring. A second advantage of an SRF deflecting cavity is its ability to operate at higher deflection voltage without thermal or electrical breakdown, which is not possible with copper deflecting cavities due to pulse heating problems.

Our goal for the SPX R&D phase is to demonstrate the fabrication of suitable SRF deflecting cavities that (1) meet the technical specifications (as outlined below) , (2) are compatible with the APS storage ring operation, and (3) have acceptable operational reliability with minimal or no impact on the routine storage ring operation. The performance parameters for the SPX deflecting cavity are listed in table 6.1.1.

Table 6.1.1. SRF deflecting cavity parameters

Parameter	Value
Frequency	2815 MHz
Total deflecting voltage	4 ×2 MV
x-ray pulse length [full width at half maximum (FWHM)]	~2 ps
Nominal beam current	200 mA
No. of cavities/cryomodule	8 × 2 or 10 × 2

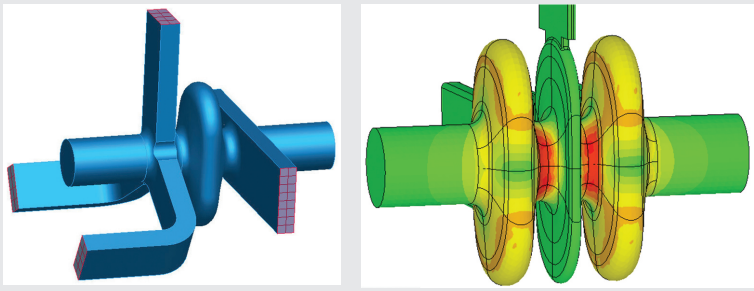
Since 2007, we have done feasibility studies, rf design simulation, and cavity prototyping to identify key technical challenges that need to be addressed in the R&D phase. We have achieved this goal through a partnership with Jefferson National Accelerator Facility (JLab).

Collaboration with JLab has resulted in significant and crucial progress toward a pre-R&D phase development of several prototype deflecting rf structures as potential candidates for the APS SPX cavities system. We were able to clearly identify key technical cavity design issues and fabrication challenges in this pre-R&D phase, which was supported by the Argonne Strategic Initiatives LDRD program. We are now in a prime position to launch a multi-year R&D program to demonstrate proof of principle and then to develop and fabricate a robust SRF deflecting cavities system to be installed in the APS storage ring.

The elements of the proposed 3-year R&D program are discussed below. When the program is complete, cavity design, construction, and installation would begin.

RF DEFLECTING CAVITY

We will continue our effort to further explore various cavity geometries, including single- and multi-cell structures, and decide on an optimized geometry that meets the SPX technical specifications. We will concentrate our effort on three potential candidates: a single-cell cavity with a beam-pipe waveguide damper (fig. 6.1.1), a single-cell cavity with on-cell waveguide damper (fig. 6.1.2), and a three-cell cavity (fig. 6.1.1). We will explore the pros and cons of each of the above geometries through detailed design, simulation. and prototyping.



SC cavity designs

Fig. 6.1.1. *Single cell with beam-pipe waveguide coupling (left) and a three-cell cavity in π/2 mode (right).*

Prototype SC cavities

Fig. 6.1.2. Prototypes of waveguide on-cell coupling.

HOM/LOM DAMPERS

The key to a successful deflecting cavity is managing higher order and lower order modes (HOM/LOM) excited within the cavity. To achieve the level of damping required at the APS, several monopole modes and vertical dipole modes in the cavity have to be sufficiently damped to meet the vertical stability impedance requirements for the stored beam. We will explore different waveguide damping geometries, including cold and warm damping sections, to efficiently extract HOM/LOM power without impacting the main deflecting mode operation.

CRYOMODULE

We will design and prototype an appropriately sized cryomodule that can house either a string of 8 to 10 single-cell cavities or 4 three-cell cavities. Because of the large number of penetrations required (due to multiple waveguide ports), it is important to develop a high performance cryomodule that meets the requirement for cavity rf power. We will implement improvements to the cryomodule thermal and magnetic shields during the prototyping phase.

RF CONTROL

A robust and reliable low-level rf (LLRF) control system is required to meet the stringent amplitude and phase errors requirements and to regulate and control the deflecting cavities fields while providing rf system diagnostics. We will explore and develop a suitable LLRF control system for the deflecting cavities system.