Design of the new sub-micron protein crystallography beamline at SSRF

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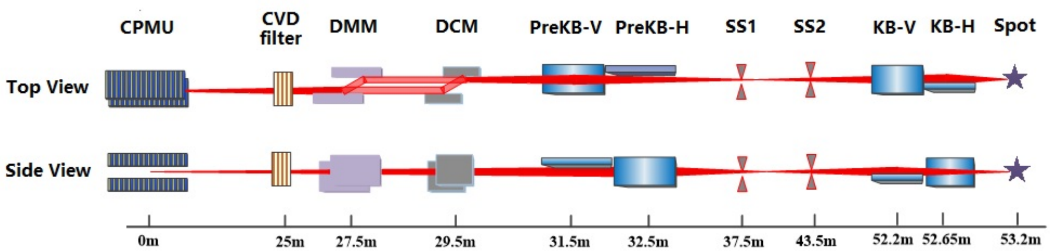
Many important proteins, such as the membrane proteins including G-protein coupled receptors (GPCRs), form notoriously small, weakly diffracting, and radiation-sensitive crystals. These crystals are intractable to conventional crystallography (MX) beamlines, e.g. several operational beamlines at SSRF. The new sub-micron (0.5 micron focusing beam) MX beamline BL04U, named as membrane protein crystallography beamline (MPX), is designed in the Phase II project and planned for commissioning in early 2020.

The beamline is designed to run at 5∼25 keV with the minimum focused spot size $1\times0.5\ \mu m^2$ (FWHM). A two-stage focusing scheme was selected for this beamline. The optical setup of choice is shown in the figure. The electron energy of the SSRF storage ring operates at 3.5 GeV, so the higher harmonics in the spectrum of a cryogenic permanent magnet undulator (CPMU) can provide high brightness X-rays in 5∼25 keV. There are 160 periods in the 3.2 meters CPMU which could provide ≥1T peak magnetic field. A liquid nitrogen cooled double crystal monochromator (DCM) in the case of high resolution mode or a double multilayer monochromator (DMM) in the case of high flux mode will be used to monochromatize the beam while a set of two-stage focusing optics will be used to focus the beam. In each mode either DCM or DMM can be moved into the beam while the other moves out. Water-cooled slits and CVD filters are set before the DMM, which absorbs a large amount of the heat load. However, the density of heat power absorbed by the first multilayer/crystal is still very high. Both the first crystal and the second in DMM/DCM will be cooled with circulating liquid nitrogen. A pair of pre-focusing KB mirrors are used to generate a secondary source while a second pair of KB mirrors are used to image the secondary source to a half micron size beam at the sample position. The shape of all KB mirrors are elliptic cylinder, and the the tangential slope error for the second pair of KB mirrors is extremely high (<0.1 μrad). The spot size will be 1 micron when the vertical demagnification ratio is set at 77.2 and the horizontal is 179. The half micron beam will be achieved by diminishing the slits. The spot size will be 10 micron when the vertical demagnification ratio is set at 22.8 and the horizontal is 49.2. The beam could be adjusted from 1 micron to 20 micron by the control of slits based on the experimental requirement. The flux at the sample position will be 1.6×10^{11} phs/s under $1\times1\ \mu m^2$ spot size at 12 keV (DCM), and 1.6×10^{11} phs/s under $1\times1\ \mu m^2$ spot size at 12 keV (DMM).The very intensive analysis on the vibration has been done and a set of high precision tempreture/humidity control system (±0.1°C and 30% relative humidity) will be installed in the end station.



Schematic beamline optics