FEASIBILITY of a COMPACT 4.4-T CRYOGENIC PrFeB-Based WAVELENGTH SHIFTER

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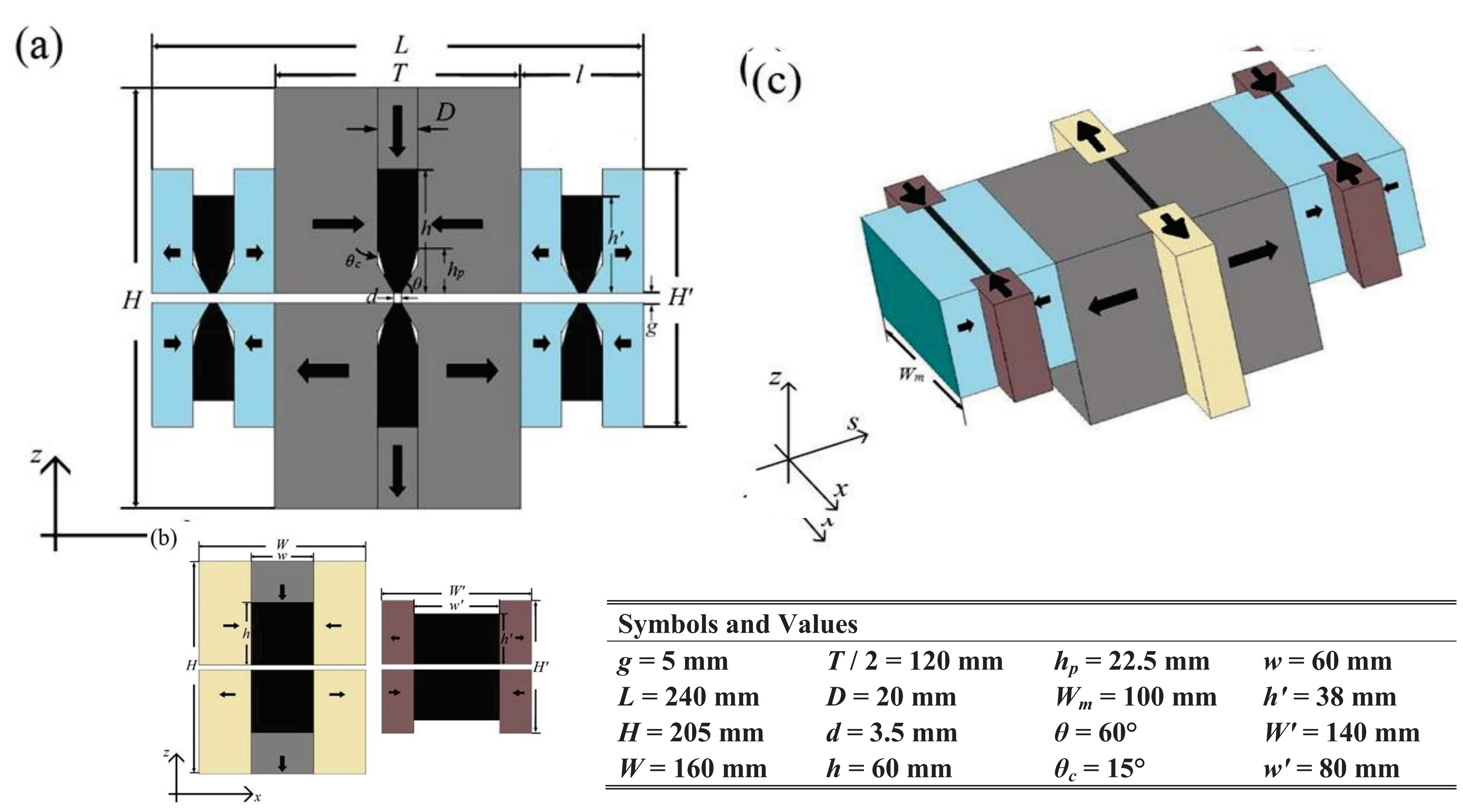
Abstract

A three-pole wavelength shifter with a cryogenic permanent magnet is designed to extend the critical photon energy in a 3-GeV storage ring to 27-keV X rays. The cryogenic wavelength shifter has a PrFeB permanent magnet and a vanadium-cobalt-steel (Permendur) pole to produce a magnetic field of flux density 4.4 T at fixed gap 5 mm. The magnet structure is optimized to prevent irreversible demagnetization of the permanent magnet near 300 K. A 77-K cryo-cooler is used to cool the magnets and to maintain the magnets at a uniform temperature, 77 K, in the vacuum vessel. This work describes the advanced design of the magnetic field and the simulations of the cooling temperature for the compact wavelength-shifter magnet.

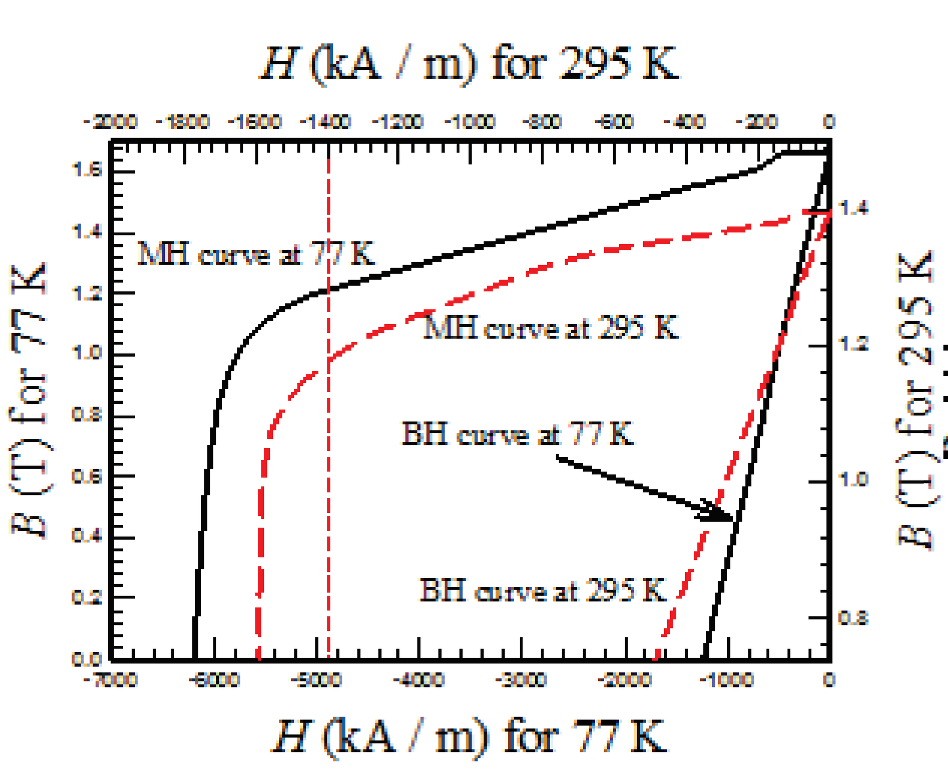
Simulating model of magnet array



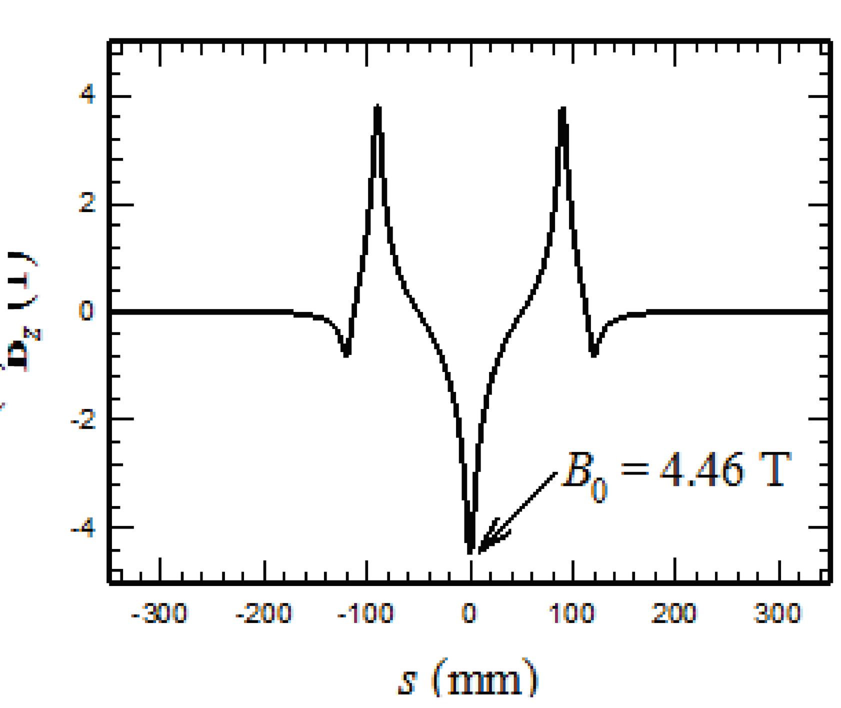
Symbols and Values			
$g = 5$ mm	$T/2 = 120$ mm	$h_p = 22.5$ mm	$w = 60$ mm
$L = 240$ mm	$D = 20$ mm	$W_m = 100$ mm	$h' = 38$ mm
$H = 205$ mm	$d = 3.5$ mm	$\theta = 60°$	$W' = 140$ mm
$W = 160$ mm	$h = 60$ mm	$\theta_c = 15°$	$w' = 80$ mm

(a) Side view of WLS. (b) Lower part of WLS model.

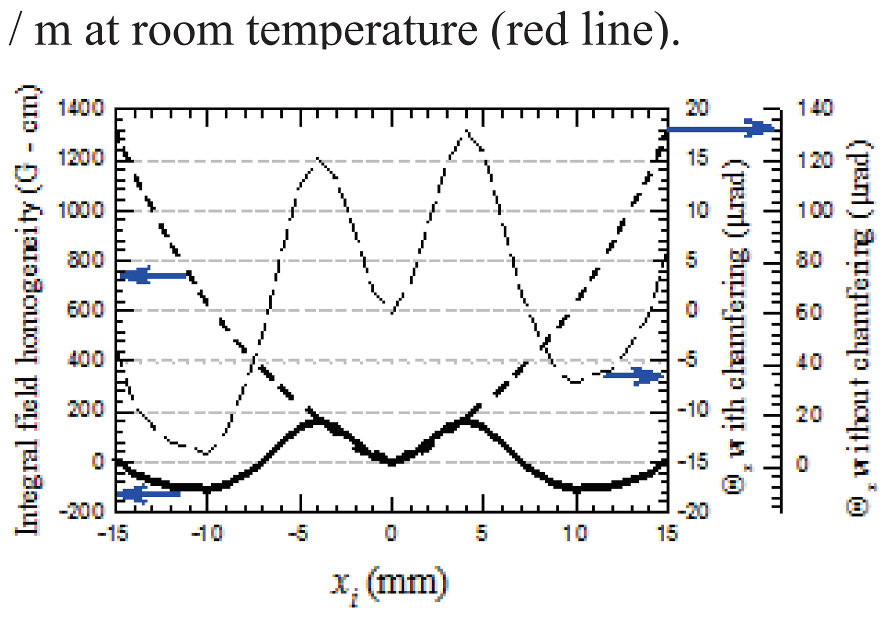
WLS is composed of one main-pole to produce the high magnetic field and two end-poles to compensate integration of the magnetic field on longitudinal direction. The material of the poles is made of the vanadium permendur steel. We adopt the PrFeB magnet (B_r = 1.67 T, the demagnetized curves shown in Fig.). The magnetic field is calculated by using the OPERA- 2D and 3D code.



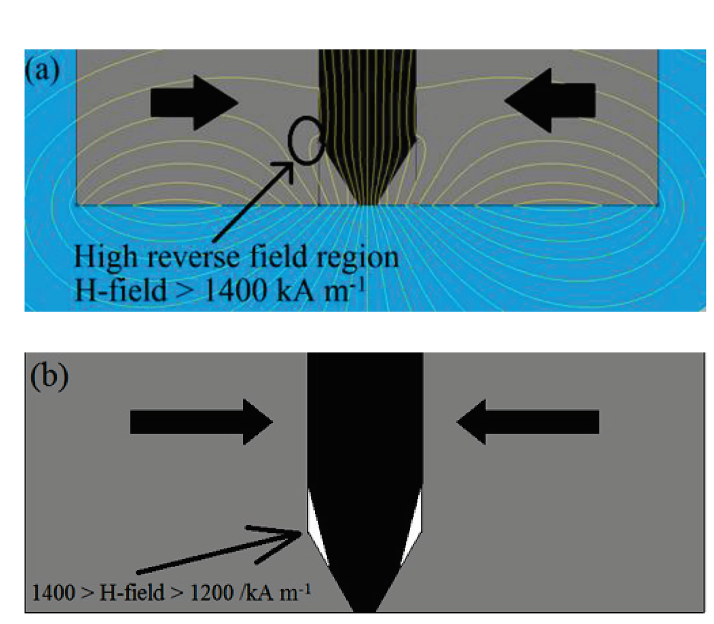
The demagnetized curves of the PrFeB magnets. B_r = 1.67 T, H_{CB} = 1240 kA / m, and H_{CJ} = 6200 kA / m at 77 K (black line). B_r = 1.4 T, H_{CB} = 1010 kA / m, and H_{CJ} = 1680 kA / m at room temperature (red line).



The distribution of magnetic flux density on axis.

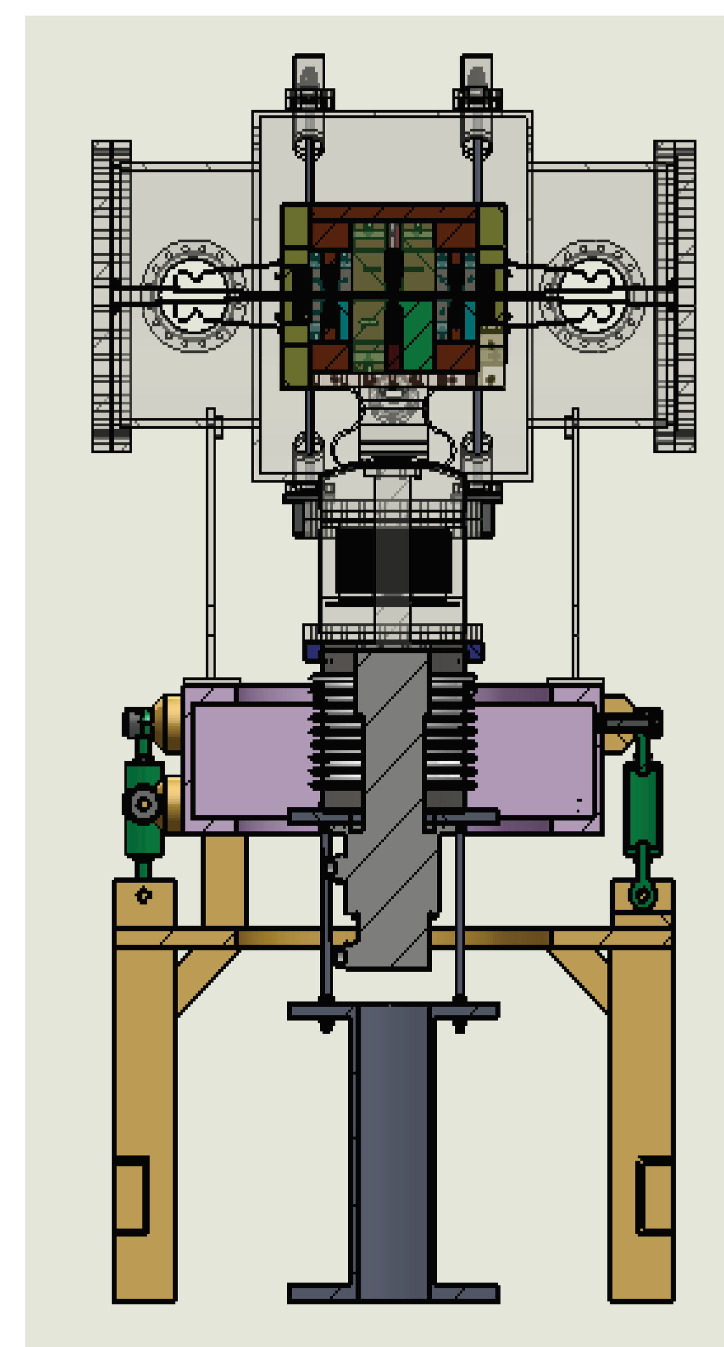


Integration of Bz with respect to s as a function of transverse position with (bold-solid line) and without (bold-dashed line) chamfering the compensating poles. The transverse deflection angle with (dashed line) and without (bold-dashed line, too) chamfering are also shown to the vertical axis to right.

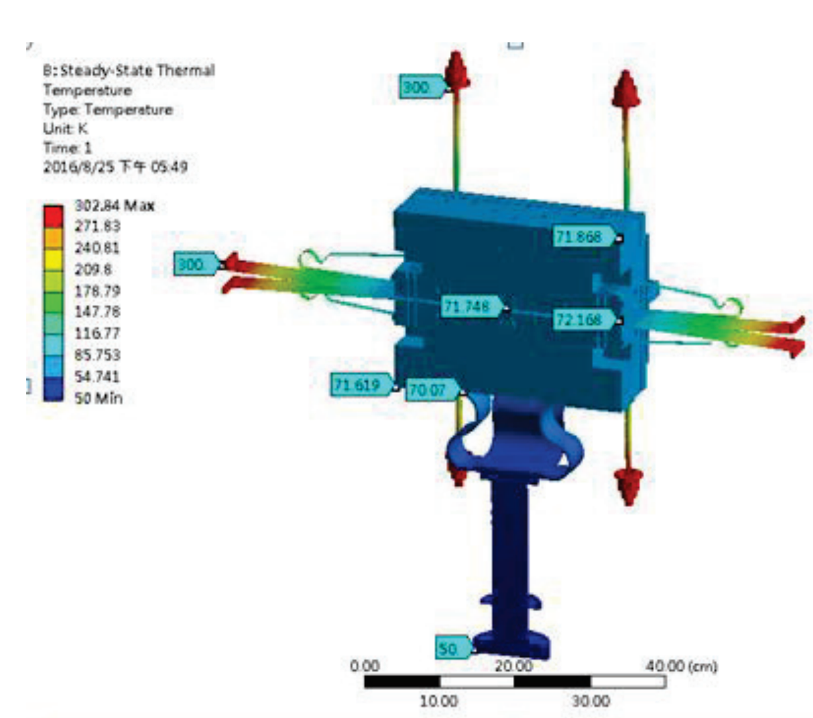


The iron poles are modified as in Fig. The iron poles near the region of large reverse field are chamfered. After chamfering the iron pole, the reverse field decays immediately; the large reverse field is almost eliminated.

Cooling method and heat load analysis



The permanent magnet wavelength shifter has a small fixed gap 5mm. For reaching UHV, the magnet array's vacuum must be independent with cold head's vacuum system. Therefore, different vacuum system is isolated by an inner stainless steel welding bellows, which cooled by cold head at the one side, and the other side connected to a copper base. The copper base will fixed with four flexible copper foils, which contact with the magnet array. The magnet array would set in the chamber by 8 suspensions, which could hang the magnet array.



Conduction Heat (W)	
Suspensions	0.73 X 8
RF Transition	7.15 X 4
Others	
Image current heat	1.41 X 4
Radiation heat	28.87
Total	68.95 (W)

Heat load from different parts

The temperature distribution of magnet array is very important for keeping the magnetic field uniformity. For making sure the magnet array would working under 77 Kelvin temperature, the flexible copper cooling foil are cover on the end of the magnet array. And the magnet array is totally covered by copper holder, which could decrease the temperature gradient of each magnet.

Conclusion

After considering the engineering feasibility, the cryogenic PrFeB-based wavelength shifter has been designed. The central field can attain as high as 4.46 T. The region of good field is 40 mm; the integral multipole field error has been optimized to be less than 100 G cm. The intrinsic reverse field in the magnetic circuit can be weakened on chamfering the iron pole near the region of large reverse field. This design is also applicable for a low-cost strong magnetic source.