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The Nanohana 2 GeV Synchrotron light source

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Abstract

Nanohana SR light source has been planned to be constructed in Chiba prefecture, Japan. The Nanohana is a synchrotron light source proposed for mainly industrial users. The electron storage ring has been designed to operate at injection energy of 500 MeV with a nominal energy of 2 GeV. The lattice is a Chasman–Green type with straight sections for up to six insertion devices. Several modes of operation are optimized to accommodate high-field superconducting wigglers, mini-pole undulators and VUV/SX undulators. Conceptual design of the synchrotron light source is presented.

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1. Introduction

The synchrotron radiation machine for the Nanohana SR facility, in Chiba prefecture (Japan) has been designed in collaboration between Budker Institute of Nuclear Physics and Kawasaki Heavy Industries Ltd. It comprises a 50 MeV linac injector, a 500 MeV booster synchrotron, two beam transfer lines and a 2 GeV electron storage ring as shown in Fig. 1. The main goal of the Nanohana design was to construct a rather compact design (less than 110 m in circumference), low-budget, reliable and efficient industrial SR source. That low horizontal emittance is not necessary for industrial applications to obtain the results of industrial SR user needs investigation, so the value $\varepsilon_x \leq 70$ nm-rad was confirmed. Other owners' requirements were:

- Critical radiation energy from BM of 4 keV;
- Spectral radiation brightness from BM $> 10^{13}$ phot/s/mm^2/mr^2/0.1%BW;
- Number of the BM beam line ports is 32;
- Beam lifetime is more than 10 h.

2. Lattice design

We chose a pure Chasman–Green [1] eight-fold symmetry lattice because it has a compact cell with small number of magnetic elements, large dynamic

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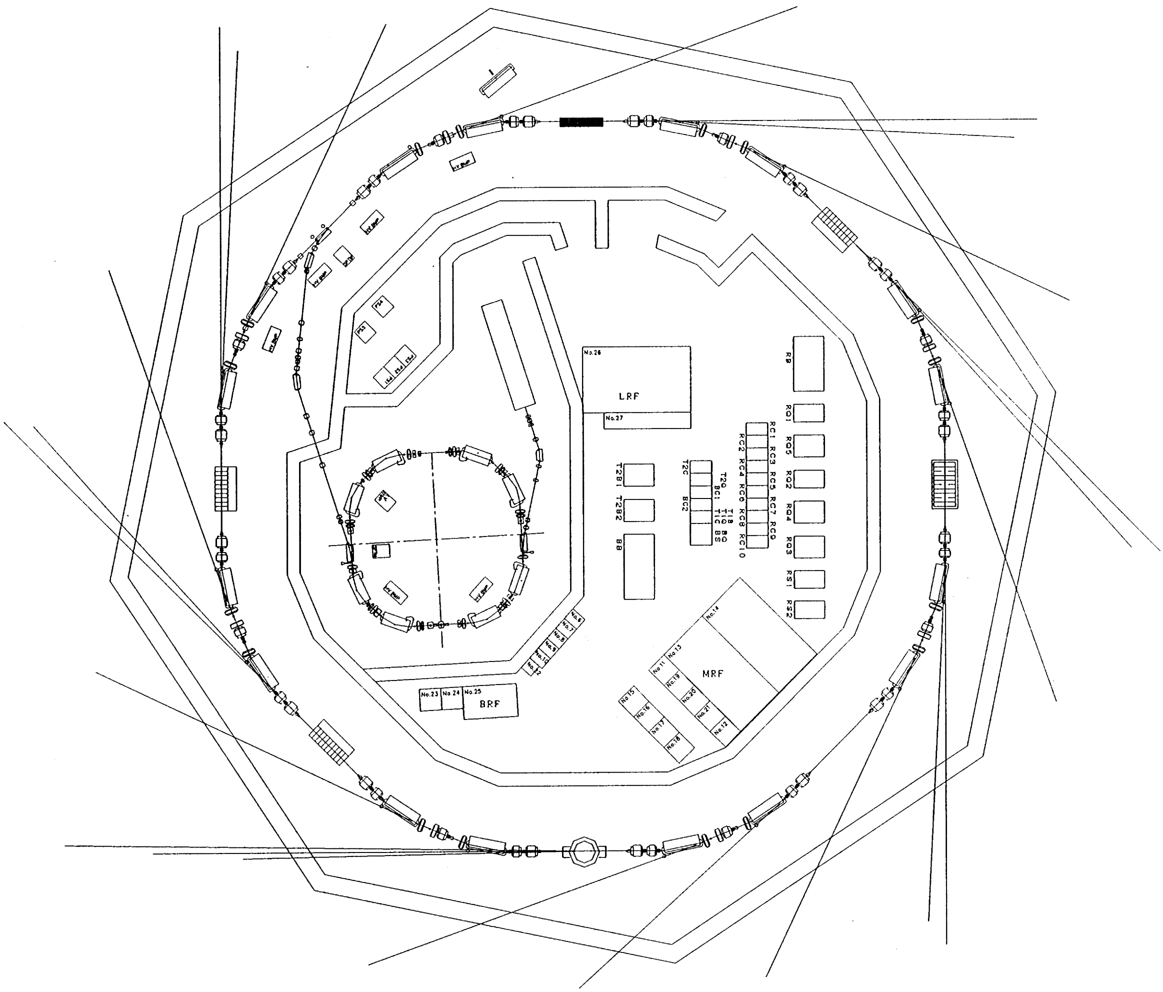

Fig. 1. General layout of the Nanohana facility.

aperture and provides good machine performance. To improve user characteristics of the ring, several IDs will be installed in the straight sections, optimized for each type of ID.

The Nanohana lattice cell includes two bending magnets, five quadrupoles, three sextupoles and a 4.5 m straight section. In spite of the small number of quadrupoles the lattice is rather flexible and provides three modes of operation:

- the basic mode (BS), which is relaxed in the view of beam-focusing and convenient for commissioning and machine adjustment,
- the low-emittance mode (LE), which provides two-fold reduction of emittance,
- the low-beta mode (LB), intended for installation of small-gap mini-undulators and high-field wigglers without deterioration of machine performance.

For the sake of brevity, lattice functions are shown in Fig. 2 only for the low-beta mode. Lattice functions for the basic mode are typical for any Chasman–Green cell and lattice functions for the low-emittance mode are the same but with a non-zero dispersion function in the straight sections.

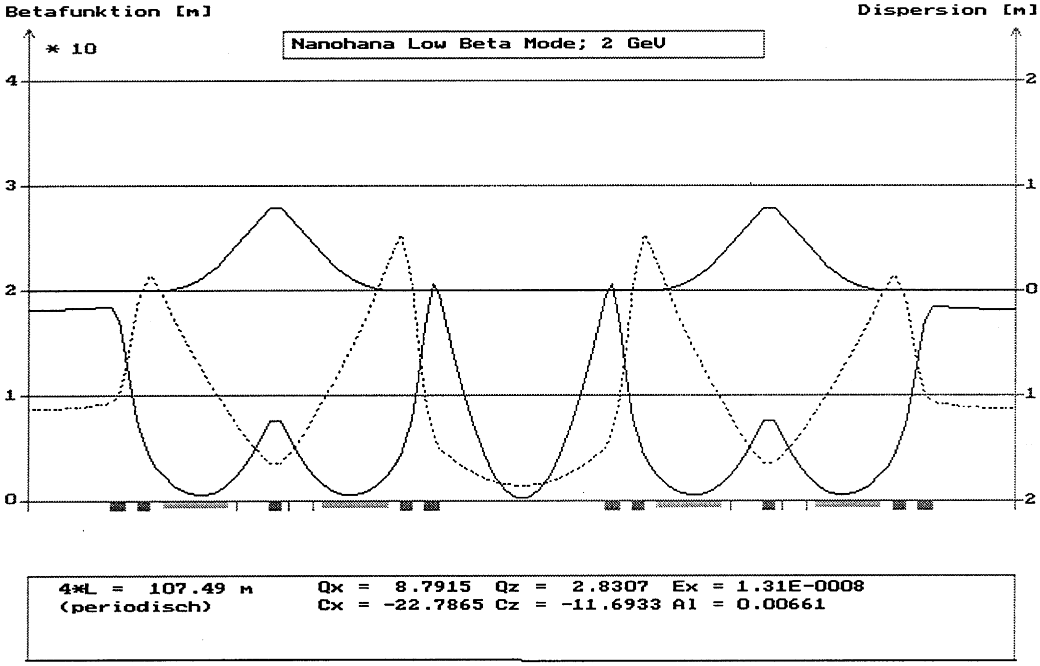

Fig. 2. Lattice functions for the LB mode: lower curves are the horizontal (solid) and vertical (dashed) beta functions, upper curve is the dispersion function.

Table 1
Nanohana parameter list

Parameter	BS	LB	LE
Circumference (m)	107.488		
Revolution time (ns)	358.544		
Revolution frequency (MHz)	2.7891		
Energy (GeV)	2.0		
Current (mA)	300		
No. of straight sections	8×4.5 m		
Hor.betatron number	6.79	8.79	6.79
Ver.betatron number	2.82	2.83	2.83
Hor.chromaticity	− 13.2	− 22.8	− 12.1
Ver.chromaticity	− 6.8	− 11.7	− 6.6
Compaction factor $\times 10^3$	6.6	6.6	8.5
Natural emittance (nm-rad)	65.2	52.4	28.6
Relative energy spread	8.2×10^{-4}		
Energy loss/turn (bend.) (keV)	320		
Energy loss/turn (IDs) (keV)	77.3		
Transverse damping time (ms)	4.4		
Synchrotron damping time (ms)	2.2		
Radio frequency (MHz)	178.5		
Peak RF Voltage (MV)	1.2		
Synchrotron tune	0.0062		
Synchrotron frequency (kHz)	17.404		
Rms bunch length (cm)	1.48		
Energy aperture	$\pm 2.4\%$		
Harmonic number	64		
Beam lifetime (h)	> 10		

Table 2
Undulators' parameters

Name	λ_0 (mm)	g (mm)	N_p	K_{max}	B_0 (T)	λ_1 (Å)
U1	6	2	100	0.4	0.71	1.96
U2	20	10	150	0.7	0.38	6.53
U3	30	10	100	2.0	0.71	9.79
U4	40	10	175	3.8	1.01	13.05

The main parameters of the storage ring for the three operational modes are summarized in Table 1.

A serious problem for beam lifetime is the mini-undulator (MU) insertion with the pole gap as small as 2 mm. To get an elastic scattering lifetime more than 15 h with the MU pole gap closed up, vacuum of 1 nTorr and vertical beta at the MU location around 1 m are required [2]. That is one of the reasons for the low-beta lattice modification.

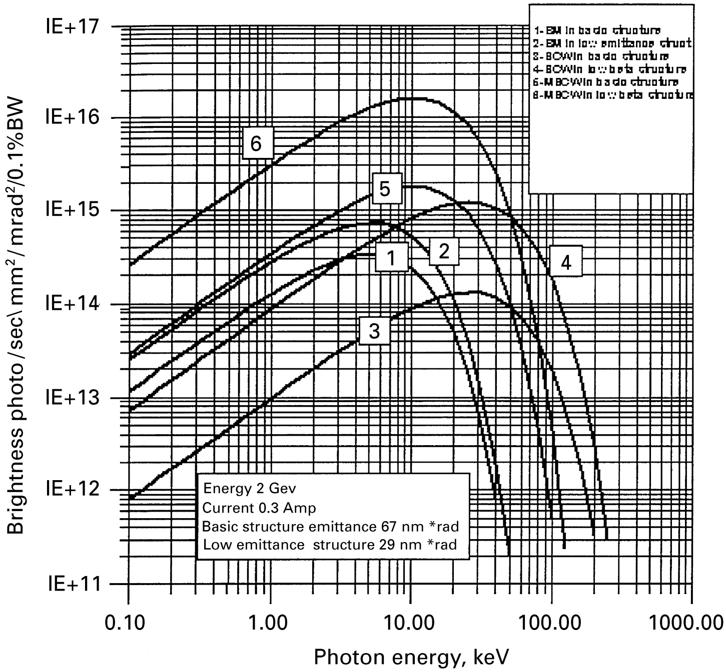

Fig. 3. Central spectral brightness from the bending magnet, 7.5 wiggler and 3.0 T multipole wiggler. Legend: 1 and 2 – bending magnet is the basic and LE modes; 3 and 4 – SCW in the basic and LB mode; 5 and 6 – MSCW in the basic and LB mode.

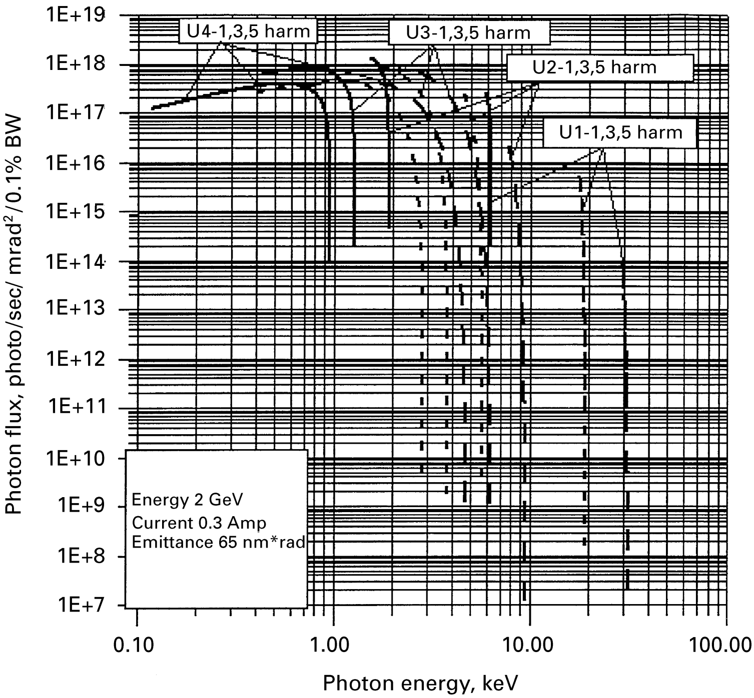

Fig. 4. Spectral brightness from the undulators. Legend according to Table 2.

3. Radiation parameters

Sources of radiation in the Nanohana storage ring will be the bending magnets and insertion devices installed in the six straight sections, each 4.5 m long. To evaluate radiation parameters the following set of IDs has been used: a 3-pole 7.5 T superconducting wavelength shifter (SCW) [3], a 20-poles 3.0 T multipole superconducting wiggler (MSCW) [4], three different VUV undulators and mini-undulator which are all of the Ne–Fe–B type. Undulator parameters are listed in Table 2 with the following legend: λ_0, g and N_p are the period, gap and number of periods, K_{max} and B_0 are the maximum undulator factor and field amplitude and λ_1 is the fundamental wavelength.

Central radiation brightness for different sources is shown in Figs. 3 and 4 for energy $E = 2.0$ GeV, beam current $I = 300$ mA and emittance coupling factor $\kappa = 1\%$.

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