Insertion Devices

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INTRODUCTION

SPring-8 has the highest beam energy, 8-GeV, among the third generation light sources in the world. By using in-vacuum undulator technology, therefore, we can raise the upper limit of the fundamental photon energy of undulator radiation up to 40 keV without any unreasonable heat load, which means that the utilization of high-field wigglers is not so important at SPring-8. However, one may point out that such a high beam energy is unsuitable for the utilization of undulator radiation in the vacuum ultraviolet(VUV) region since the very high power radiated from the planar undulator with high deflection parameter, K, may bring damage in the beamline optics. In case of planar undulators, the most of the power is derived from the higher harmonics, which are unwanted light in the ordinary optical measurement in the VUV region. Therefore, such a problem can be solved by developing helical undulators for circular polarization or figure-8 undulators for linear polarization.

According to the above policy, we are constructing ten insertion devices; seven in-vacuum undulators for x-ray region, helical and figure-8 undulators for VUV region and an elliptic wiggler for very hard x-ray region. They will be installed in the ring by the end of FY1997.

The main parameters and spectral brilliance of the devices are shown in Fig. 1 and Table 1, respectively.

In-Vacuum Undulators

The most important advantage of the in-vacuum undulators is that the vacuum gap is equivalent to the magnetic gap. Therefore, the magnetic gap or vacuum gap can be made as small as possible according to the operation modes of the ring. In case of SPring-8, the narrowest gap of 10 mm will be realized. As a result, the period length of undulator can be made very short, typically 2 cm. Therefore, we can obtain the first harmonic in the hard x-ray region.

Although this device has several disadvantages, we have solutions. The most serious problem is the outgassing from rare earth permanent magnets because of its porous structure. To eliminate such outgassing, the magnet surface should be coated by Ni-electro-plating or TiN ion-plating. In case of electro-plating, the sharp edge of the permanent magnet should be rounded, which causes volume error in the magnets. This problem is serious for minipole undulators where very small magnet chips will be adopted. To avoid that, TiN coating by ion plating has been developed by Sumitomo Special Metals Company. As another merit, this coating is very hard, so that the surfaces of the magnets may be well protected.

The second problem is irreversible demagnetization during heat cycle for UHV bakeout, which may cause magnetic field errors in the undulator. To avoid that, we have to adopt permanent magnets with high coercivity at the baking temperature for UHV. In addition to that, we have to anneal the magnets at the temperature somewhat higher than the bakeout temperature, typically ten degrees higher. Although the magnetic flux is lost slightly, the irreversible flux loss during UHV bakeout can be made negligible. This treatment is called "AGING".

Table 1 Main parameters of the insertion devices to be installed by the end of FY1997.

Name	Type	Polarization	λ_u cm	N	G_{min} mm	B_y/B_x tesla	K_y/K_x	F_{max} ton	$\varepsilon_1(\varepsilon_c)$ keV	PT_{max} kW	PD kW/mr^2	Beamline	Remarks	Installation
U032V-1	pure	linear	3.2	140	8	0.78	2.33	3.7	5.1-18.2	11.0	470	BL-41IN	in-vacuum	Dec. `96
U032V-2	pure	linear	3.2	140	8	0.78	2.33	3.7	5.1-18.2	11.0	470	BL-09IN	in-vacuum	Dec. `96
U032V-3	pure	linear	3.2	140	8	0.78	2.33	3.7	5.1-18.2	11.0	470	BL-39IN	in-vacuum	Dec. `96
U032V-4	pure	linear	3.2	140	8	0.78	2.33	3.7	5.1-18.2	11.0	470	BL-46IN	in-vacuum	March `97
U032V-5	pure	linear	3.2	140	8	0.78	2.33	3.7	5.1-18.2	11.0	470	BL-10IN	in-vacuum	Sept. `97
U024V	hybrid	linear	2.4	188	5	0.9	2.0	2.5	8.3-24.0	14.7	706	BL-47IN	in-vacuum	Sept. `97
VU037V	pure	vertical	3.7	40×2	8	0.45	1.55	-1.0	7.4-15.7	2.4	136	BL-45IN	in-vacuum	Dec. `96
HU120	pure	circular	12	12×2	20	0.57	6.4	0.76	0.12-4.6	7.2	0.037	BL-25IN		March `97
F8U100	pure	linear	10	44	20	1.0/0.25		0.53				BL-27IN		Sept. `97
EW120	pure	circular	12	37	20	1.1/0.1	12.3/1.1	11.5	(47)	21.6	35	BL-08IN		March `97

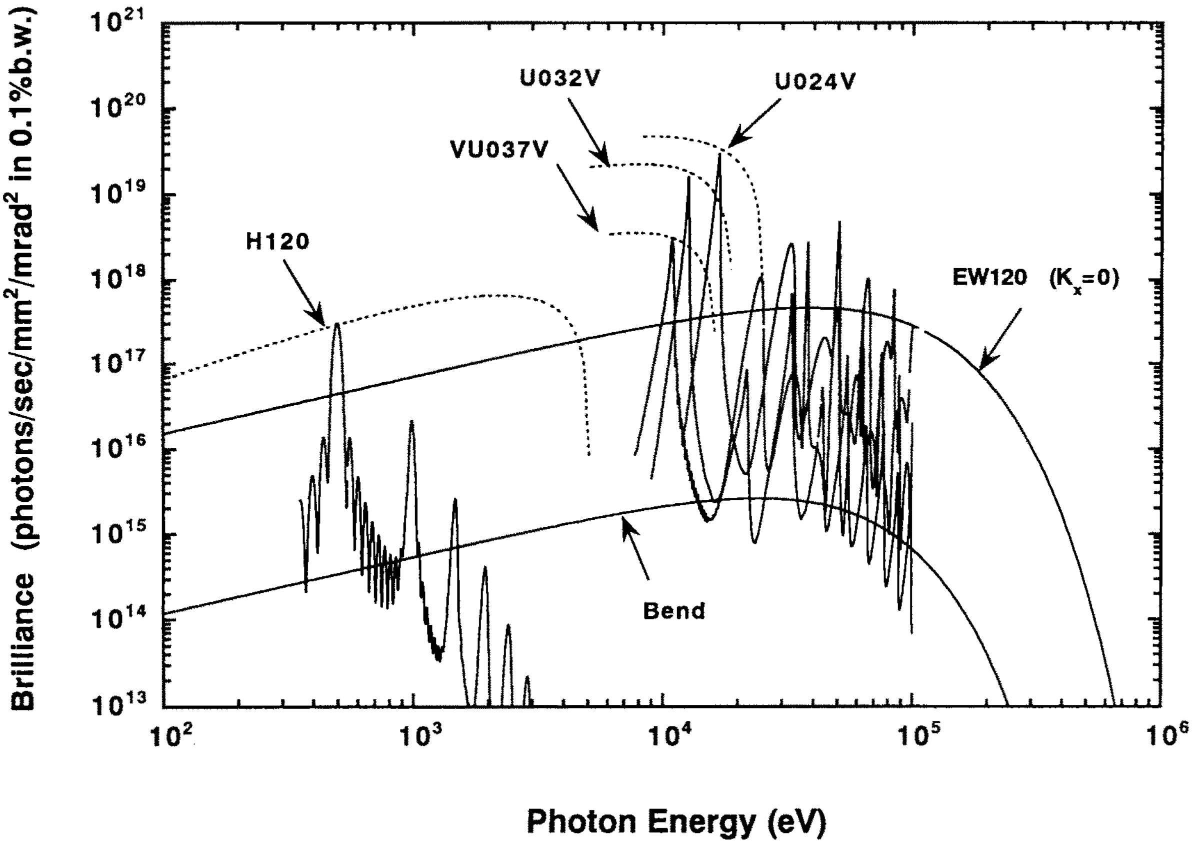

Fig.1 Spectral brilliances obtained from the insertion devices to be installed by the end of FY1997.

The last problem is that cement or glue for assembling undulator magnets is unsuitable for UHV system. Instead of cement, mechanical clamps should be adopted. In this point of view, SmCo magnet is unsuitable since this material is easily broken to powder by mechanical pressure.

At SPring-8, in-vacuum undulators with period length below 4.5 cm or helical undulator below 7 cm will be of in-vacuum type. New permanent magnet material, NEOMAX33UH, will be adopted. The bakeout temperature around 140℃ may be possible, so that ultrahigh vacuum can be obtained easily. The magnets for the in-vacuum undulators will be coated by TiN vacuum ionplating of 5 μm thickness. As shown in Table 1, we are constructing five in-vacuum undulators of standard type (λ_u=3.2 cm and N_{period}=140), an in-vacuum hybrid undulator with permendur poles (λ_u=2.4 cm and N_{period}=188) and an in-vacuum vertical undulator (λ_u=3.7 cm and N_{period}=80).

Undulators for VUV Region

If we desire 1st harmonic with low photon energy, we have to apply high K value. In case of planar undulators, however, high-K-value setting brings high power density as well as so many higher harmonics, and they bring damage in the optics. For example, we suppose a planar undulator with the period length of 10 cm, K value of 4.7 and the number of periods of 45. Although high on-axis brilliance can be obtained as 1.5×10^{18} at 500 eV, the on-axis power density is estimated to be very high as 100 kW/mrad^2, which is too high for VUV optics. Such high power density is derived from so many higher harmonics with high intensity (Fig.2a).

On the other hand, the higher harmonics, in case of helical undulators, are existing off-axis, so that the most of them disappear on axis as shown in Fig.2b where the spectral brilliance obtained from the example of helical undulator with the same period length of 10 cm and K value of 3.34 is also shown. The on-axis power density is calculated as only 0.6 kW/mrad^2, so that the damage in the optics can be minimized. Therefore, most of the VUV

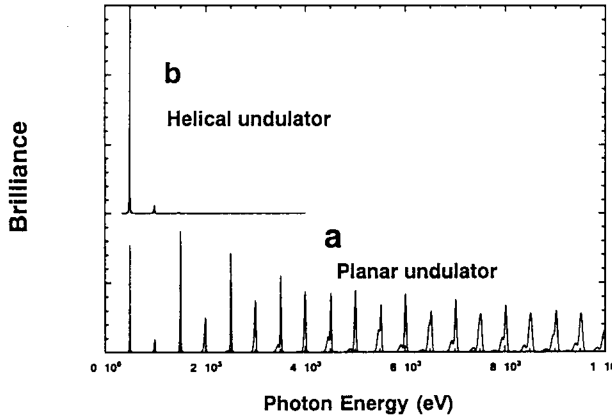

Fig. 2 Comparison between the spectra obtained from the planar and helical undulators.

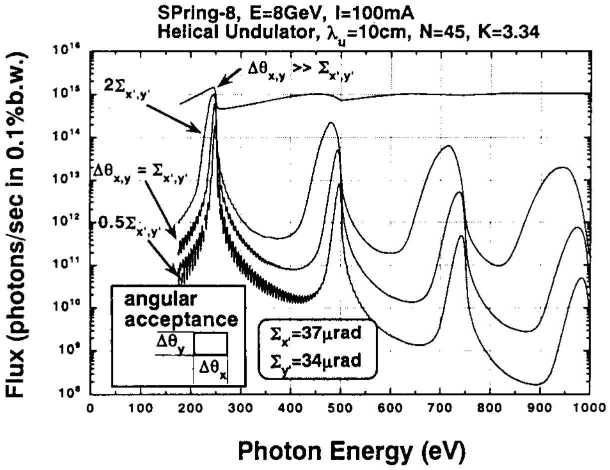

Fig. 3 Spectral fluxes obtained from the helical undulators for various acceptances

beamlines at SPring-8 will be for the use of circularlypolarized synchrotron radiation. However, we should note that too wide angular acceptance may bring unreasonable heat load in the optics as shown in Fig. 3, where the spectral fluxes for various angular acceptances are calculated. The unwanted flux is found to decrease for smaller acceptance. As shown in Table 1, a twin helical undulator system of out-of-vacuum type (λ_u=12 cm and N_{period}=12×2) is being constructed to obtain fast switching of helicity. The switching will be made by the local bump of the orbit with 5 kicker magnets (Fig. 4). The magnetic design is shown in Fig. 5. The vertical field is obtained by the central magnet arrays, the horizontal field by the outer magnet arrays. The helicity

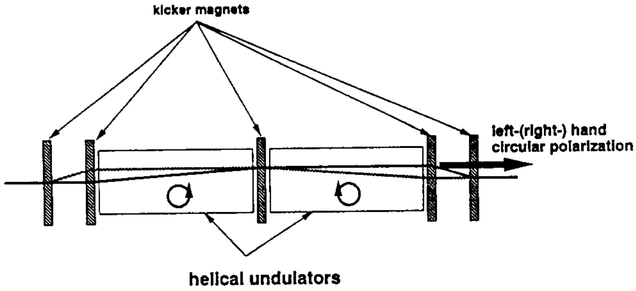

Fig. 4 Twin helical undulator system for variable polarization using kicker magnets.

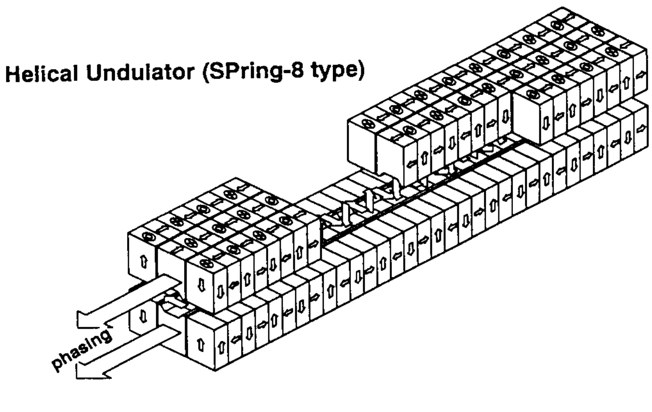

Fig. 5 New design for helical undulators.

of the undulator magnet can be varied by translating the central magnet arrays.

As an undulator with low on-axis power density and linear polarization, a figure-8 undulator (λ_u=10 cm and N_{period}=44) is being constructed. The design details are reported in this article by T. Tanaka.

Elliptic Wiggler

To obtain circularly polarized radiation in the energy region up to 300 keV, an elliptic wiggler of out-of-vacuum type (λ_u=12 cm and N_{period}=12×2) is being constructed. Although the magnetic design is almost the same as that of the helical undulator, the helicity change can be made by translating the outer magnet arrays as well as the horizontal field can be varied by translating the upper or lower outer magnet arrays in the opposite direction. The spectral brilliance and circular polaization obtained from this device is shown in Fig. 6. One can see that higher polarization can be obtained by horizontal field can be varied by translating the upper or lower outer magnet arrays in the opposite direction. The spectral brilliance and circular polaization obtained from this device is shown in Fig.6. One can see that higher polarization can be obtained by applying higher horizontal field, but this sacrifices the brilliance.

Standardization

At SPring-8, the maximum length of the insertion device is 4.5 m. For effective standardization, the device may be divided into 3 units of 1.5 m long per each. We intend the standardized unit should be adaptable for most of the insertion devices including in-vacuum type. A complete insertion device will be consist of 3 units mounted on the common base, so that the space between adjacent units can be minimized to 50 μm to eliminate phasing errors as well as kick errors . Figure 7 shows the plan view of the standard in-vacuum undulator.

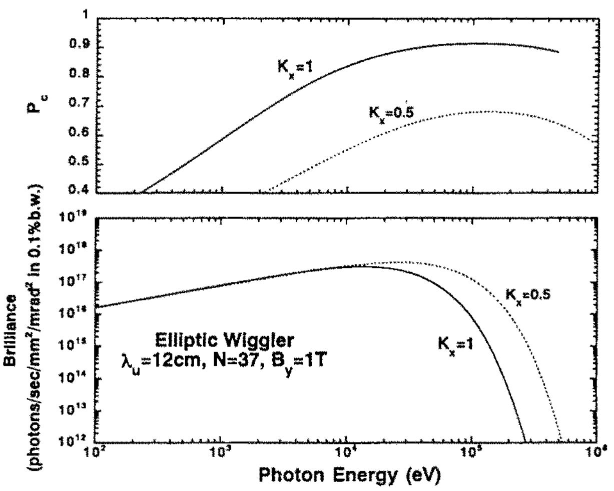

Fig.6 Spectra and ciecular polarization obtained from the elliptic wiggler.

Figure 8 shows the details of the neighborhood of the magnetic gap.

Schedule

We give priority to the completion of one of the standard in-vacuum undulator as a pilot device, which will be completed in the end of FY 1995. Toward the commissioning in February, 1997, three standard in-vacuum undulator including the pilot one and a in-vacuum vertical undulator will be installed in the ring. The other devices will be installed by the end of FY 1997.

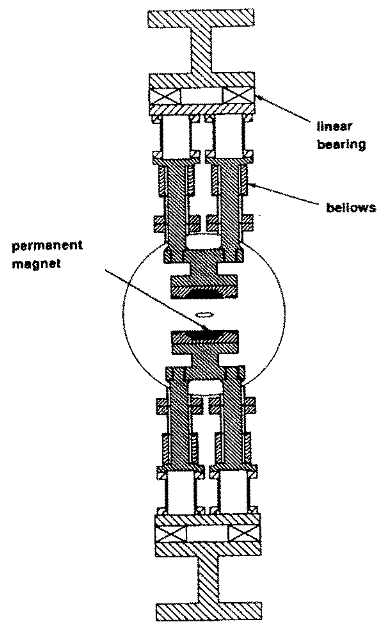

Fig. 8 Cross-sectional view of the in-vacuum undulator.

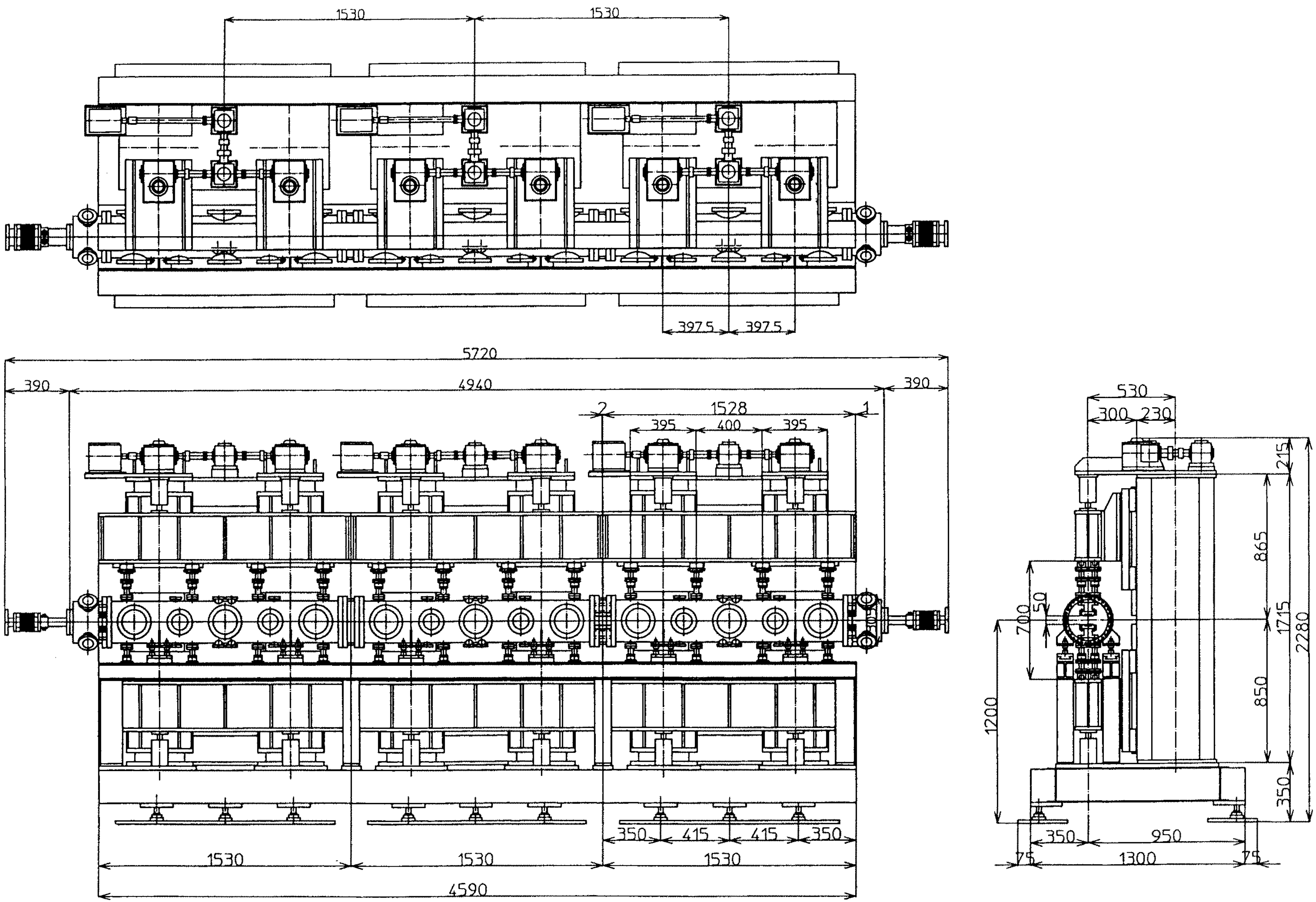

Fig.7 Plan view of the in-vacuum undulator, U032V. The device is composed of three units.