Control of the Bunch Length on the UVSOR Storage Ring [II]

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The experimental study to make the bunch length of the electron beam short is in progress on the UVSOR storage ring by means of reducing a momentum compaction factor. A part of the preliminary results was reported in the last issue of the activity report.

The experiment has been carried out in the single-bunch mode at an electron energy of 600 MeV. At the injection point, the momentum compaction factor α was experimentally determined to be 0.035, and the bunch length was measured to be 260 ps (2σ)[1]. According to a model calculation[2], we synchronously changed excitation currents of the quadrupole (Q) magnets step by step to reduce α after the beam injection. A new accelerator control system[3] using μ-VAX computers with an application "UCOSS" has capacitated to make this experiment. To derive α at each operating point, the horizontal beam displacement as a function of the RF frequency and the synchrotron oscillation frequency (f_s) were measured. The bunch length was also measured directly using a fast photomultiplier with a single photon counting. The bunch length at a low beam current was successfully shortened down to ~40 ps, which was consistent with the other two measurements. In the very low α region, however, it was found out that effect of the second order term in the momentum compaction factor α_2 revealed itself, and then the beam lifetime became short. It is obviously a serious problem for stable operation with low α.

Because the second order term originates in the chromatic effect of the Q-magnets on the dispersion function, the effect of α_2 should be compensated with focusing sextupole (SF) magnets. The strength of the sextuple magnets was chosen to correct the chromaticities so far. Figure 1 shows the RF frequency dependence of f_s for various strengths of the SF-magnets at an operating point with α = 0.0009. Values of α_2 were derived by a fitting analysis with an analytical formula[4] including the α_2 term. A linear dependence of α_2 on the strength of the SF-magnets can be seen in the insert. In this case, the best correction was achieved when the SF strength was reduced to ~ 86 % of the initial value.

A direct measurement of bunch length with a streak camera[5] was in progress. The strength of SF-magnets was reduced to make α_2 nearly zero in the measurement, so that the momentum compaction factor was further reduced. In figure 2, the measured bunch length is plotted as a function of f_s which was measured simultaneously with the bunch length. A shape of a focusing image on a screen of the streak camera was taken account to analyze the data. Time resolution of the streak camera was estimated to be 16 ps, which is mainly due to time jitters of the streak trigger. Typical bunch profiles measured by the streak camera are shown in the inserts. The bunch length is almost proportional to the synchrotron oscillation frequency over the wide range, as predicted by theory. The shortest bunch length realized was 23 ps (~ 7 mm), and the estimated momentum compaction factor was 0.0003.

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References

1) A. Lin, H. Hama, S. Takano and G. Isoyama, Jpn. J. Appl. Phys. 31 (1992) 921.
2) J. Staples, LATTICE, LBL report No. 23939 (Lawrence Berkeley Laboratory, Berkeley, 1987).
3) N. Kanaya, H. Hama, J. Yamazaki, O. Matzudo and G. Isoyama, in preparation.
4) H. Hama, S. Takano and G. Isoyama, to be published in Nucl. Instr. and Meth.
5) Y. Tsuchiya, A. Takeshima, E. Inuzuka, K. Suzuki, M. Koishi and K. Kinoshita, Proc. of 16th Int. Cong. on High Speed Photography and Photonics (Strasbourg, 1984) Vol. 491.

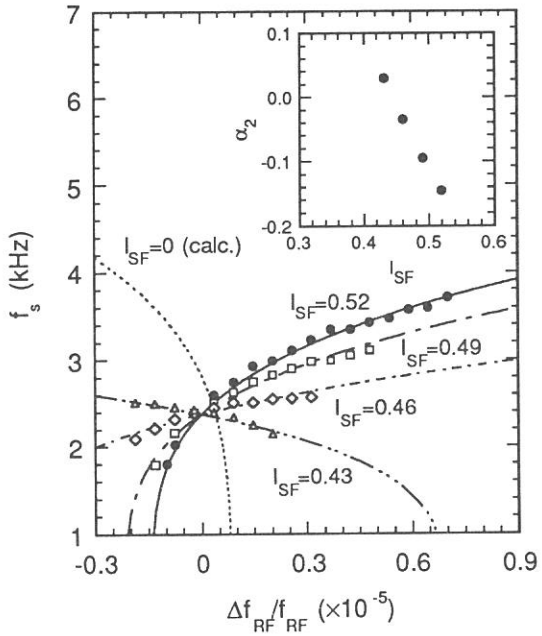

Fig. 1. Measured synchrotron oscillation frequency f_s as a function of the RF frequency for various strengths of the focusing sextupoles at the operation point with α = 0.0009. The theoretical curve for α_2 = + 0.518 is also shown by the dotted line. Experimantal values of the second order momentum compaction factor are plotted as a function of the strength of the sextupoles in the insert.

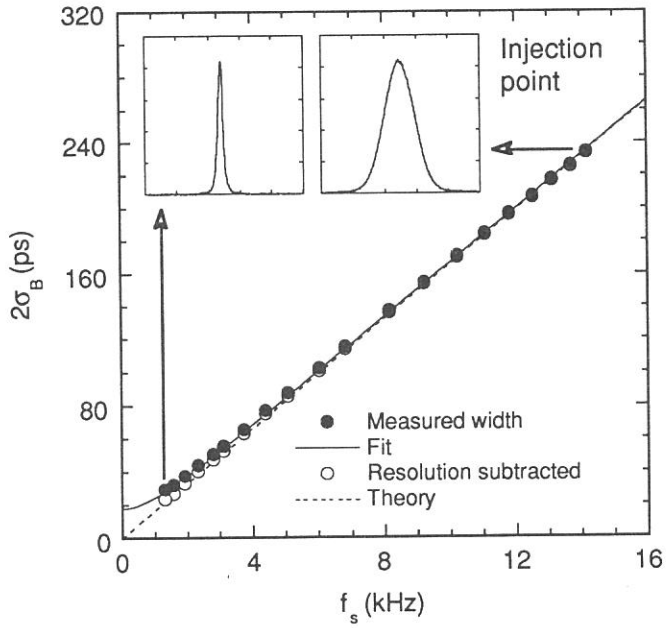

Fig. 2. Measured bunch length with the streak camara as a function of the synchrotron frequency observed simultaneously. The solid line is a fit taking account the time resolution of the streak camera. Typical bunch profiles are shown in the inserts.

Lasing of a Free Electron Laser in Visible on the UVSOR Storage Ring

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Free electron laser (FEL) experiments are in progress on the UVSOR storage ring. FEL gain at a wavelength of 488 nm was measured with a conventional undulator at an electron energy of 500 MeV [1]. As the measured peak gain of 8×10^{-4} for the beam current of 10 mA/bunch was marginal to achieve lasing, the undulator was remodeled into an optical klystron (OK) in order to increase the gain. The gain with the OK was measured at the wavelength to be 0.4 % at 10 mA/bunch [2]. An optical resonator was installed for oscillation experiments, and the first lasing was obtained at a wavelength of 456 nm on March 8, 1992 [3].

The optical resonator consists of a pair of spherical mirrors separated by a distance of 13.3 m, which is a quarter of the circumference of the storage ring. As there is not enough room in the upstream of the OK, the optical cavity is asymmetric. Radii of curvature of the front and the rear mirrors are 8 and 6 m, respectively. The radius of the waist for the TEM_{00} mode is 0.48 mm. The filling factor calculated from overlap with the electron beam is 0.33. We have used mirrors coated with dielectric multilayer.

The geometrical axis of the optical cavity is aligned with the electron beam in the OK by using spontaneous radiation. In order to synchronize the light pulse stored in the cavity and electron

bunches, the cavity length is precisely tuned such that the width of the temporal profile of spontaneous radiation stored in the cavity is minimized.

For the oscillation experiments, the storage ring is operated in the two-bunch mode at the energy of 500 MeV. Figure 1 shows spectra of output light from the optical cavity for beam currents ranging from 21.5 down to 9 mA/bunch, which are measured with a monochromator equipped with a one-dimensional photodiode array. The laser line at λ= 456.6 nm is clearly seen in Fig.1 (a) and (b). The linewidth is approximately $\Delta\lambda$ = 0.2 nm (FWHM) after the monochromator resolution is subtracted. The relative linewidth $\Delta\lambda/\lambda$ is 4×10^{-4}. Figure 1 (c) and (d) show the spectra just above and below the lasing threshold, respectively. The macro-temporal structure of the laser light is observed with a PIN silicon photodiode. When the rf frequency is tuned to give the maximum output power, a quasi-periodic pulsed

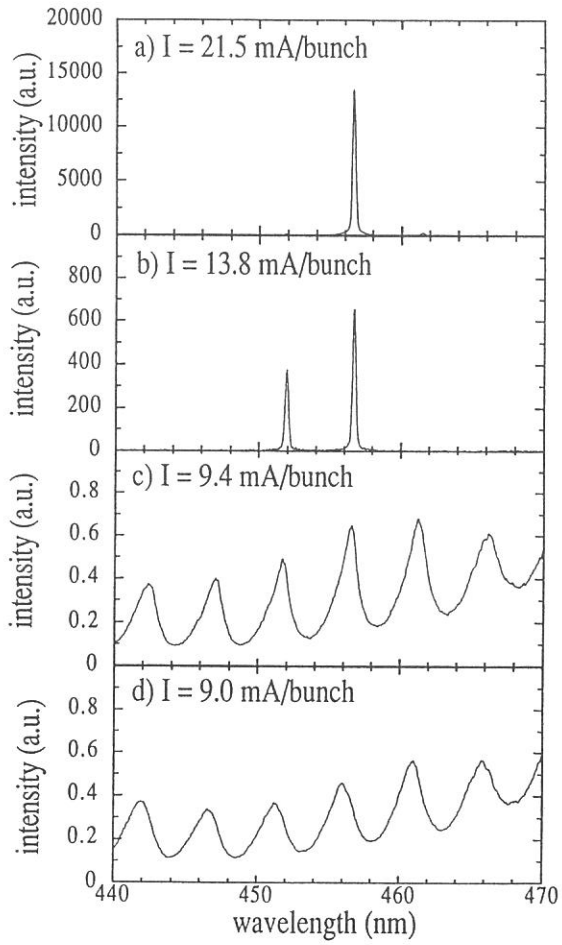

Fig. 1. Spectra of output light transmitted by the front mirror of the optical cavity.

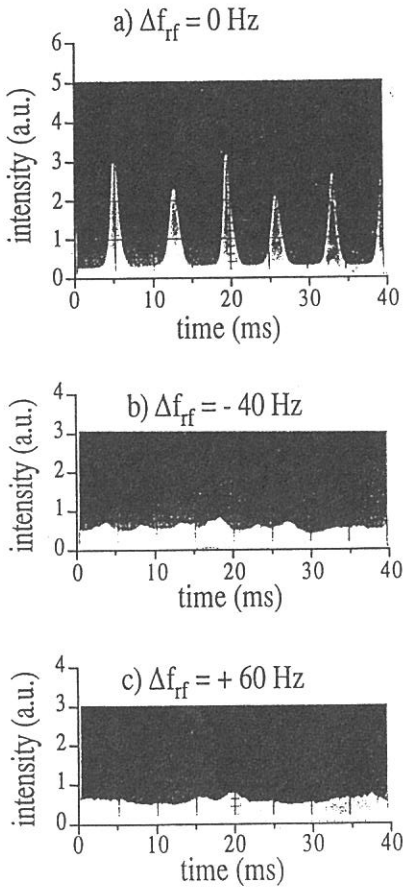

Fig. 2. Time profile of the laser light.

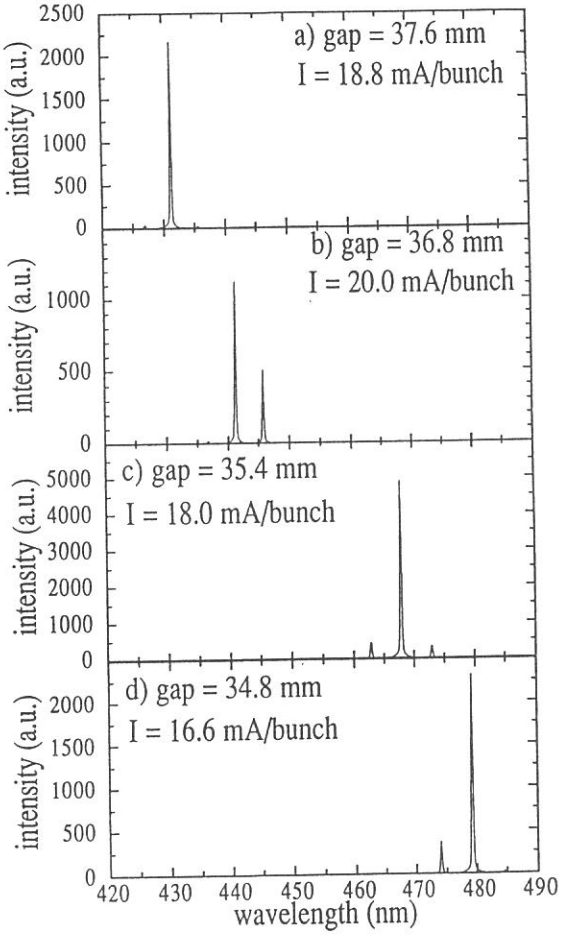

Fig. 3. Tunability of the laser wavelength.

structure is observed as shown in Fig. 2 (a). The rise time and the typical repetition period are approximately 1 and 7 ms, respectively. When the rf frequency is detuned, the CW structure appears as shown in Fig. 2 (b) and (c), though the intensity fluctuates. The maximum time-averaged output power is 0.2 mW when the beam current was 23 mA/bunch. From the measured duty ratio of macro pulse structure and the bunch length, the peak output power of the micro pulse is estimated to be more than 0.8 W. Lasing continues over the range from 430 to 480 nm when the magnet gap in the undulator sections is varied. Figure

3 shows some of the spectra of the laser light at various wavelengths.

References

[1] S. Takano, H. Hama, G. Isoyama, A. Lin and N.A. Vinokurov, Jpn. J. Appl. Phys. **31**(1992)2621.

[2] S. Takano, H. Hama and G. Isoyama, UVSOR Activity Report 1991, p. 4: S. Takano, H, Hama and G. Isoyama, submitted to Jpn. J. Appl. Phys.

[3] S. Takano, H. Hama and G. Isoyama, submitted to Nucl. Instr. and Meth. Phys. Res.

Apparatus for photoemission spectroscopy of solids and solid surfaces at BL2B1

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We have constructed a new experimental system for the photoemission and absorption spectroscopy at BL2B1, where a 2-meter grazing incidence monochromator (Grasshopper Mark XV) has already been installed. It covers a photon energy range from 40 to 800 eV, and is suited to the core-level photoemission and absorption spectroscopy.

Figure 1 shows the schematic diagram of the apparatus. It consists of three chambers. Spectroscopic measurements are performed in the main chamber equipped with a double-pass CMA (Cylindrical Mirror Analyzer) with a coaxial electron gun, a LEED (Low Energy Electron Diffraction) optics, a quadrupole mass spectrometer, a gas doser, etc. The base pressure of the main chamber is $< 5\times10^{-11}$ Torr after a bakeout. The photoabsorption spectroscopy is measured via monitoring a total photoelectron with a picoammeter connected to the sample. The angle-integrated photemission spectroscopy is measured with the CMA. Constant initial state spectroscopy, constant final state spectroscopy, and Auger electron spectroscopy can also be measured. The time dependence of the incident light intensity and the transmission function of the monochromator is monitored with a gold grid located across the light beam.

The preparation of the samples is carried out in the preparation chamber which is equipped with a file, an evaporation source, and so on. The base pressure of this chamber is $< 1.5\times10^{-9}$ torr.

When samples are changed, the insertion chamber is opened to air, and pumped for ~1 hour. Then the sample can be transferred into the preparation chamber and the main chamber via a magnetically coupled linear-rotary motion device. The pressure of the main chamber is maintained below 4×10^{-9} Torr during the transfer and returns to $\sim1\times10^{-10}$ Torr in a few minuets after closing the valve.

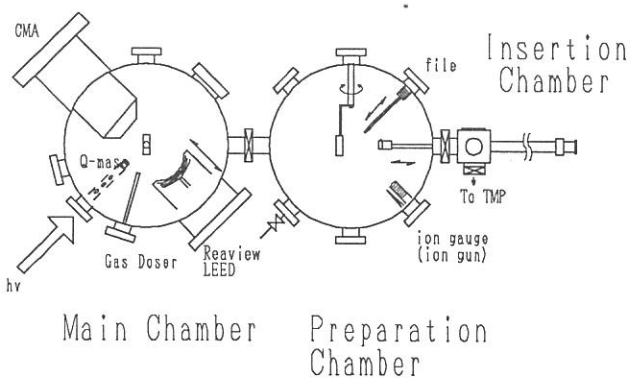

Figure 1

A Schematic diagram of an experimental apparatus at BL2B1

Beamline BL4B: Construction of an Apparatus for the Study of Synchrotron Radiation-Excited Semiconductor Processes

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Synchrotron radiation (SR) is a powerful tool for studying surface physics and structure determination, and very active research is being undertaken in many SR facilities over the world. In recent years, another capability of SR, i.e. its application to microfabrication, is being explored. Its application to X-ray lithography is a typical example. Since semiconductor processes using SR have been expected to open its new potentialities of applying it as a fabrication tool, its research has attracted considerable attention from not only the technological viewpoints but also purely scientific ones of developing a new field in molecular science, i.e. surface photochemistry in the vacuum UV region /1/. In order to realize these goals we are now constructing an apparatus on beamline BL4b to study SR-excited semiconductor processes /2/.

The design for the whole apparatus has been just completed. It consists of five ultrahigh vacuum chambers, i.e. an etching chamber, an epitaxial growth or CVD chamber, an XPS surface analysis chamber, a sample storage chamber, and an air-lock chamber. The reaction mechanisms and dynamics of semiconductor processes will be the focus of our research using this apparatus. In addition to XPS, in-situ observations of adsorbed species by infrared absorption spectroscopy as well as detection of the desorbed ionic species by the time-of-flight mass spectroscopy are in preparation.

Figure 1 illustrates the top view of the apparatus connected to Beamline BL4B. SR beam is incident from the left side of the etching chamber. Design parameters are as follows:

Epitaxial chamber : Pumped by a 500 ℓ/sec turbomolecular pump(TMP). Expected base pressure: 1×10^{-9} Torr. Sample is heated by PBN/PG heater up to 1200 ℃, RHEED: Electron energy is 30 kV, Differentially pumped by 150 ℓ/sec TMP. IR port: BaF_2 window, incident angle, 82.5 $\pm$ 5 degrees.

Etching chamber : Pumped by 300 ℓ/sec TMP. Expected base pressure: 1×10^{-9} Torr. Sample heating and cooling: 100 K - 600 K, IR port: BaF_2 window, incident angle, 85 $\pm$ 5.

Sample storage chamber : Pumped by 300 ℓ/sec TMP. Expected base pressure: 1×10^{-9} Torr. Sample holders: A sample holder cleaned by heating up to 1200 ℃ using a PBN/PG heater. Three holders for sample storage. LEED is used for surface characterization.

Air-lock chamber : Pumped by 150 ℓ/sec TMP. Expected base pressure: 1×10^{-7} Torr. Sample holder: 4 holders.

XPS chamber : Pumped by a 270 ℓ/sec ion pump, a Ti sublimation pump, and a 150 ℓ/sec TMP. Base pressure: 1×10^{-10} Torr. XPS analyzer: spherical analyzer (VSW), using a Mg K_α X-ray source. IR port: BaF_2 window; incident angle: 82.5 $\pm$ 5 degrees.

REFERENCES

(1) T. Urisu, et. al., Applied Organometallic Chemistry 5, (1991) 229.

(2) H. Ohashi, et. al., UVSOR Activity Report (1991) 15.

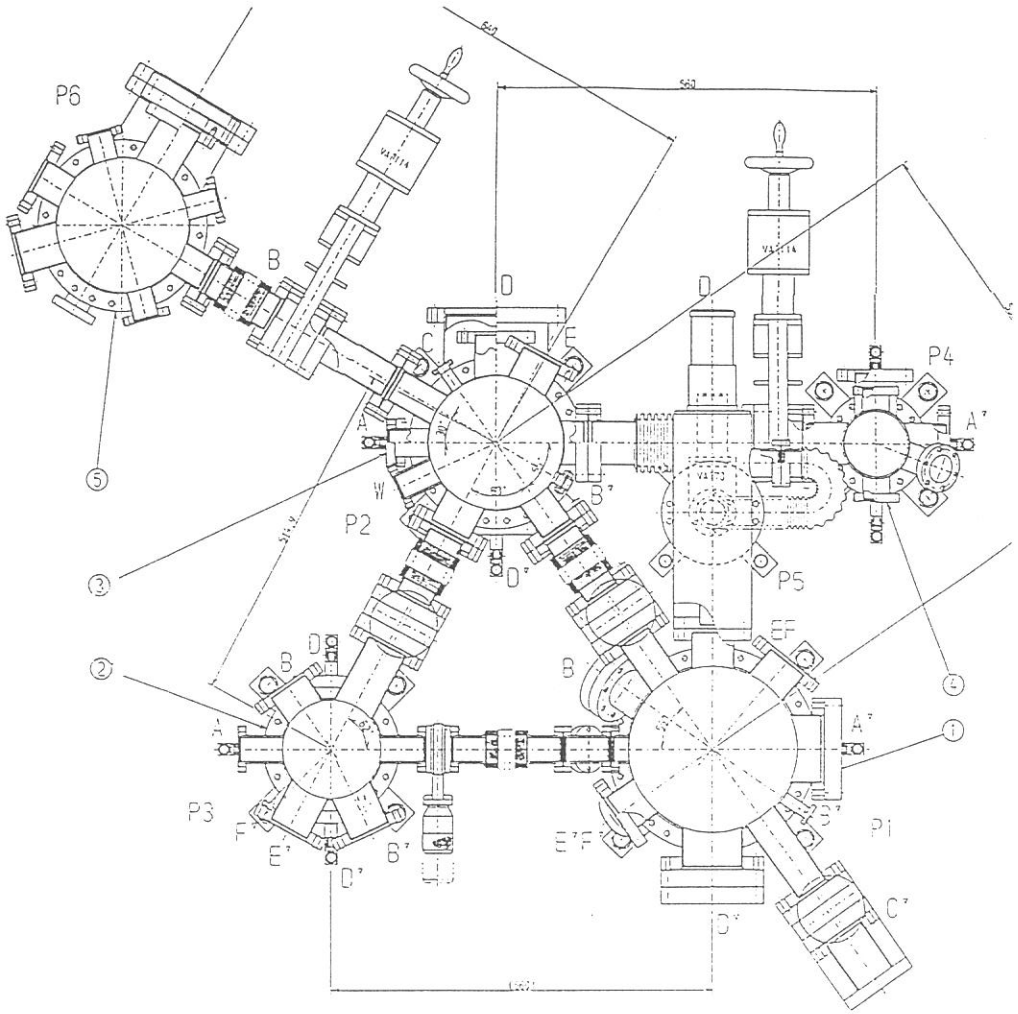

Fig. 1 Top view of the apparatus for the study of synchrotron radiation-excited semiconductor processes under construction on beamline BL4B. ① : Epitaxial chamber, ② : Etching chamber, ③ : Sample storage chamber, ④ : Air-lock chamber, ⑤ : XPS chamber.

A monochromator for measurement of fluorescence spectra of gases at the BL8B1 beamline of UVSOR

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A VUV monochromator for fluorescence measurement was recently constructed and attached to an absorption cell behind a grazing incident monochromator in the BL8B1. Fig.1 shows the optical system. The absorption cell has a quartz window and a LiF window at both sides in the direction perpendicular to the incident beam. Fluorescence from the quartz window is focused by a quartz lens on an entrance slit of a Jobin-Yvon monochromator with a multichannel detector which is placed in the air, while that from the LiF window is dispersed by a 0.28 m spherical grating with 1200 l/mm in the vacuum chamber. Thus, the fluorescence spectra of gases in the region from 110 nm to 800 nm can be observed by this optical system.

We give here some examples of fluorescence observed with this apparatus. Figures 2 and 3 show the spectra of HCl which was excited by the zero order light of the grazing incident monochromator. The energy of the incident light extends from 70 eV to 280 eV with the maximum at 150 eV. Many sharp lines in the region above 300 nm can be assigned to emissions of atomic ions Cl^+ and two lines around 120 nm to H-Lyα and neutral Cl $^2P^o$-^2P. Broad bands in the region from 200 nm to 270 nm also are attributed to overlap of many atomic lines of ions Cl^+ and Cl^{++}, although they look like a molecular structure. Photoabsorption of the Cl-L edge starts at 200 eV and can be excited by the present incident white light, while the photoabsorption cross section of the valence shell of HCl is very weak around 200 eV. Valence excitation by a He resonance line of 58.4 nm(21.2 eV) yields the fluorescence of $HCl^+(A^2\Sigma^+ \rightarrow X^2\Pi)$[1,2] in the region from 250 to 450 nm. To the contrary, the relaxation paths following the Cl-L inner shell excitation leads to dissociation of HCl.

An another example of BrCN observed with the spherical grating monochromator is shown in fig.4. All lines in this region are due to neutral and ionic atoms of C and Br. The resolution is estimated to be approximately 100 at 200 nm.

References

1. T. Ibuki, N. Sato, and S. Iwata, J. Chem. Phys. **79**, 4805(1983).
2. B. P. Tsai and L. L. Parrella, J. Chem. Phys. **76**, 745(1982).

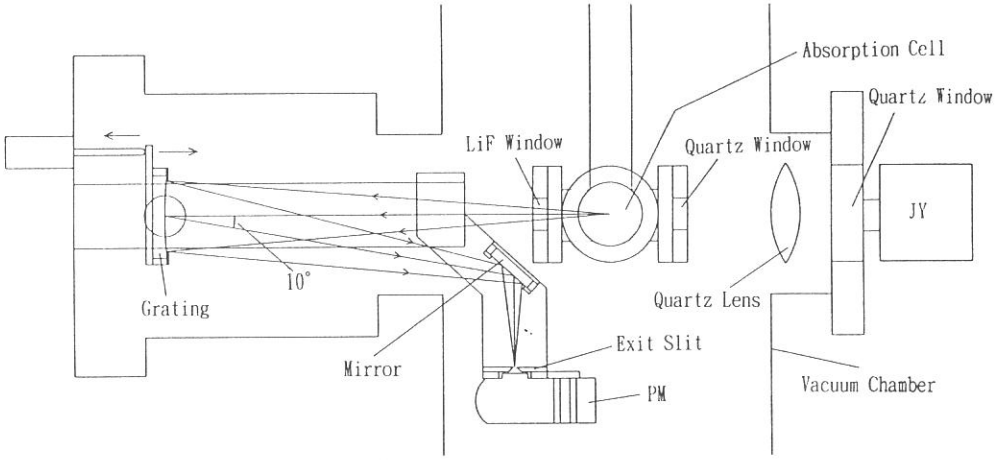

Fig. 1 Optical system for measurement of dispersed fluorescence
PM; photomultiplier, JY; Jobin-Yvon monochromator

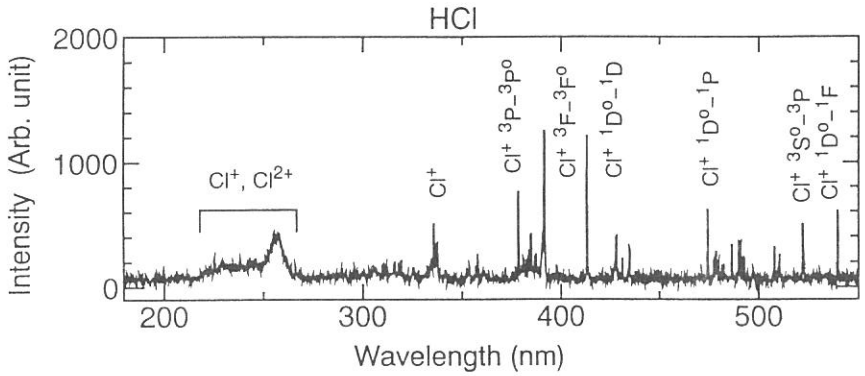

Fig. 2. Dispersed fluorescence spectrum of HCl in the region from 180 to 550 nm, measured with Jobin-Yvon monochromator in the air.

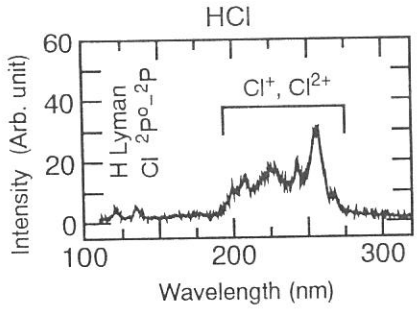

Fig. 3.
Dispersed fluorescence spectrum of HCl in the Vacuum UV and UV region

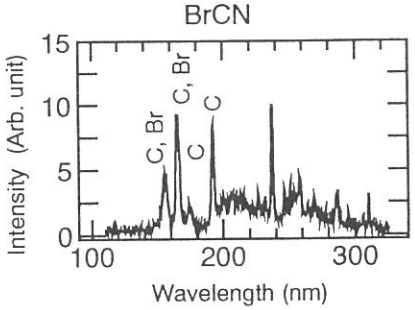

Fig. 4.
Dispersed fluorescence spectrum of BrCN in the Vacuum UV and UV region