Operation of a Narrow Gap, Short Pole Undulator at MAX I

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Abstract

At the 550 MeV electron storage ring MAX I a narrow gap (minimum 6.2 mm vacuum gap) short pole (24 mm period) is in operation. The extremely narrow gap is achieved by a squeeezable vacuum chamber which allows at the other end up to 20 mm aperture at injection. the beamsteering and lifetime reduction are controlled and well described by conventional models. The machine is well oepratable even at lowest gaps. This work presents the effects on the storage ring operation, the technical layout of the device and the chracteristics of the source.

1. INTRODUCTION

The MAX-lab [1] is built around an accelerator system consisting of a 550 MeV electron storage ring (MAX I) injected from a 100 MeV racetrack microtron. These components have been in operation over last ten years. Today a new 1.5 GeV electron storage ring is under construction. MAX I is equipped with seven beamlines out of which two are operating with undulators as light sources. The most recent of these is operating at extremely small vacuum gaps (down to 6.2 mm) [2]. To the lightport a modified SX-700 monochromator is connected [3].

The storage ring suffers somewhat of beam lifetime reduction due to the undulator and also a change in beam position and tune shifts. These effects are within control and can fully be explained by standard models.

The photon flux is lower than ultimate goals, but in good agreement with theoretical reconstructions.

2. THE UNDULATOR

As a base for the choice of the quite demanding parameters of this device lay the desire to generate highly collimated radiation in the photon energy range 250 - 600 eV. Due to the fairly low operating energy of MAX I (550 MeV) the solution lay in operating at high harmonics (10 or higher) in a device with a short period. The flux could remain high by keeping the K-value up, which in all demanded a small magnetic gap.

Scrapers were put onto the storage ring at the planned position of the undulator, and these studies [5] showed that a gap of 6-9 mm was needed to operate the machine at full energy, and a gap of 20 mm was desired at injection energy.

A design including an adjustable vacuum chamber was chosen. It has a vacuum chamber wall thickness of only 0.3 µm at the pole tips. The mechanical vacuum aperture is 1.2-1.5 mm smaller than the gap of the magnet structure. Mechanically the vacuum gap can be adjusted between 6 and 20 mm.

The hybrid magnet assembly consists of Neodymium-Iron-Boron permanent magnets and Armco Iron poles. The magnets were calibrated by controlled demagnetisation and selected from a larger batch based on magnetisation uniformity. The resulting magnetic field was further corrected by shimming. The final peak field uniformity, with an rms-variation between 0.5 and 1 % at different gaps, is, however, worse than expected. The most important parameters and dimensions of the undulator are given in table 1.

Table 1. Undulator parameters and dimensions

Period	24 mm
Number of periods	34.5
Total length (between flanges)	1036 mm
Vacuum gap	6 - 20 mm
Magnet gap	7.6 - 140 mm
Maximum peak field	0.76 T
Maximum K-value	1.68

The "phase errors" [4] have been calculated from measured data. About 50 % or more of the intensity of an ideal undulator is retained up to the 9th harmonic.

3. INFLUENCES ON THE STORAGE RING

The, in many ways, extreme parameters of the undulator are a fertile soil for fears of unpredictible and disastrous effects on the storage ring. Our experiences though show that regarding: beam lifetime, beam emittance, betatron and closed orbit shifts, MAX I is still operating according to conventional models.

3.1 Beam lifetime

The machine is today operating with a slightly modified lattice which achieves a Touschek lifetime of 15 hours at 100 mA. The predicted lifetime for operation with the undualtor is shown in fig. 1 (solid line) together with the measured lifetime. The predicted lifetime at 100 mA with an elastic scattering lifetime of 5.5 hours at a 10 mm gap and a gap independent lifetime (Touschek, Bremsstrahlung and horizontal elastic scattering) of 9 hours is given by:

$$\tau = 1/(1/9 + 1 / (0.055\, h^2)),$$

where h is the full gap in mm, and τ is the beam 1/e-lifetime in hours. The corresponding average nitrogen equivalent pressure is 2.3 10^{-9} mbar.

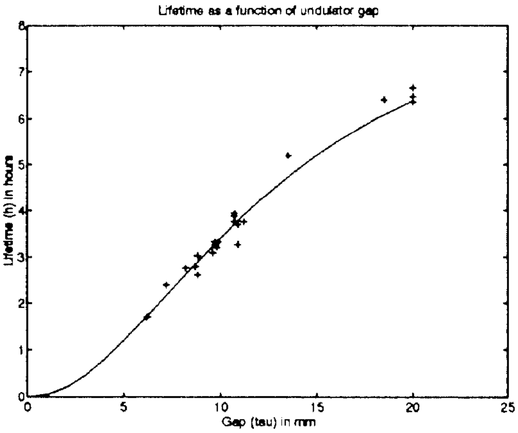

Fig 1. Lifetime as a function of undulator gap.

3.2 Emittance and tune

A over a run with the undulator is shown in fig 2. Here the device was moved from full o pen gap down to 9.7 mm, hten opened again, and finally closed down to 10.7 mm. There is no detectable change in horisontal beam size which in turn implies no change in neither emittance nor energy spread.

The vertical betatron shift was between 0 - 0.03, which complies with theory.

3.3 Closed orbit

The change in horisonatl closed orbit shows the characteristic pattern of one isolated kick around the machine. The maximum deviation is 1 mm and the pattern is in very good agreement to a simulation with the measured value (0.18 Tmm) on the remaining field integral.

A simple non-feedback correction system will be implemented in the near future.

4. PHOTON FLUXES

First measurements at the beamline showed a photon flux which was significantly lower than expected. By recalculating the theoretical spectra a more realistic situation was achieved, and the agreement between theory and reality was restored.

In fig 3 and 4 measured spectra are given, and in fig 4 the reconstructed spectrum is given along.

The reconstructed spectrum takes into account the following points:

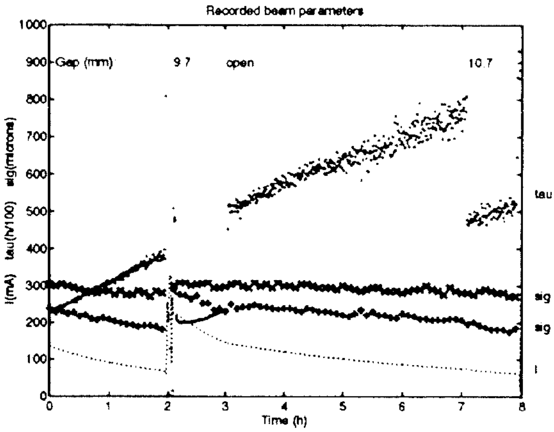

Fig 2. Recorded beam parameters.

4.1 The monochromator efficiency.

The monochromator installed in the beam line is a modified SX-700 plane grating monochromator manufactured by Carl Zeiss, Oberkochen, Germany. In fig 6 the efficiency of individual elements along with the total efficiency is given.

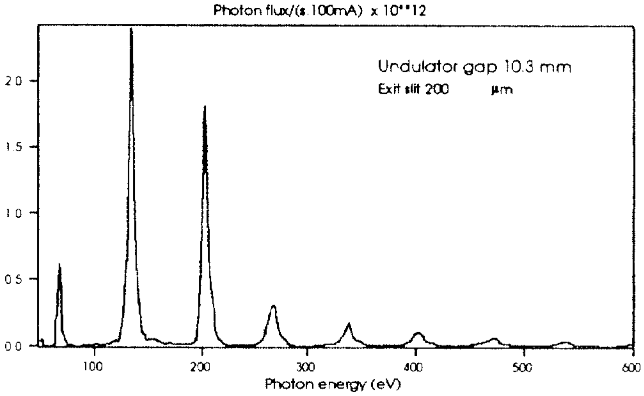

Fig 3. Measured spectrum up to above the 9th harmonic

4.2 The monochromator bandwidth.

The photon bandwidth in this monochromator is a convolution of three different factors, namely: the source size, the slope errors in the surface of the optical elements and the vertical size of the exit slit.

4.3 Other effects

- Electron beam size as given from measurements on the machine are: s_x=0.7 mm, s_x'=0.09 mRad, s_y=0.14 mm, s_y'=0.04 mRad.
- Electron beam energy spread (0.2%).
- Undulator errors.

By adding these effects to the plain calculated spectrum of the undulator (calculated by the code URGENT [6]) a good agreement can be found between measured and calculated flux (fig 4).

The measured spectrum also contain signals on the high energy side of the peaks from the undulator harmonics. They are more or less pronounced at different occasions, but so far we have not found any acceptable explanation for the effect.

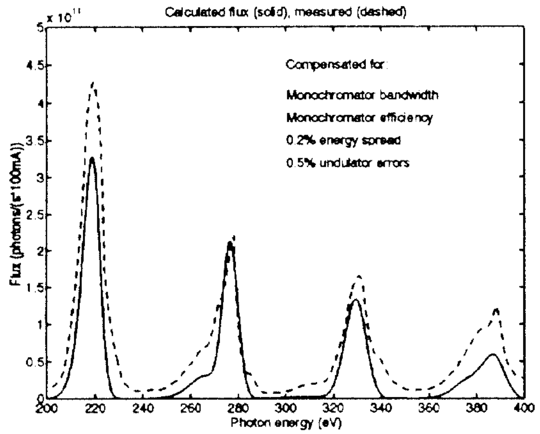

Fig 4. Measured and calculated pectra

5. THE BEAMLINE

The beam line was optimised for experiments in gas phase samples. In order to avoid fast surface contamination of the monochromator, a differential pumping station was introduced between the monochromator and the experimental station. Normally the pressure in the experimental station is kept at 10^{-5} mbar, after the differential pumping section the pressure is reduced to 10^{-10} mbar range.

A few experimental set-ups have been operating at the beam line. Among them photoelectron spectroscopy have been performed in noble gases and in a number of small molecules [7,8,9,10]. These type of experiments take advantage of the high flux obtained from the undulator. High flux allowed the use of small exit slit apertures needed in the high resolution measurements. New phenomena have been observed recently where the very high resolution obtained played a important role.

In H_2S it was observed that when a hole is created in the molecular split $2p_{3/2}$ core electrons a strong propensity rule is observed in the Auger decay $S2p^{-1} \rightarrow X^1A_1(2b_1^{-2})$. This finding may lead to a need to reinterpretate a number of high resolution Auger spectra reported in the literature [9].

An electron and ion yield detector system is also mounted on the electron spectrometer. A time of flight spectrometer (TOF) has been build and at present a few test measurements have been performed at the beam line. It is planned to study the fragmentation part way of selectively excited molecules.

Taking advantage of the differential pumping section it is planned to study the photoelectron spectra of outgassing polymers, liquids and volatile adsorbates.

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