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MONOCHROMATIC AND POLARIZED TAGGED LADON GAMMA RAY BEAM AT THE ESRF MACHINE

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Monochromatic and polarized gamma ray beams have been produced by the scattering of laser light against the high energy electrons circulating in a storage ring(1). It is possible to improve the performance of these beams by tagging the scattered electrons and with some changes in the optical properties of the stored electrons.

If the final electron is detected and its energy measured we have a tagged photon beam. In this case the energy of the scattered photon, k, is determined by the difference between the initial and the final electron energies.

The energy of the final electron can be determined using some components of the storage ring lattice as a magnetic spectrometer and measuring the displacement from the main orbit of the final electron at a selected location in the storage ring.

Assuming that the radial position of the final electron can be measured with an accuracy much better than the total radial spread of the beam at the position of the tagging detector, σ_T (i.e. the contribution of the finite size of the detectors can be neglected) and that $k \ll E$, the energy resolution is given by the linear theory of electron optics(2) as:

$$\sigma_k = E \frac{\sigma_T}{d} \qquad (1)$$

where d is the dispersion of the storage ring lattice (A_{13} or A_{16} of the transport matrix) from the interaction region to the tagging detector. So the best energy resolution is obtained at the location where σ_T/d is minimum.

The quantity σ_T/d that can be of order of 10^{-3} for most storage rings.

In this paper we present the results of a study performed for the 5 GeV storage ring of the European Synchrotron Radiation Facility that appears a very promising tool for the production of tagged Ladon beam[3]. Its essential parameters are indicated in Table I.

TABLE I - TALADON project
European Synchrotron Radiation Facility - Main parameters

Electron energy		$E = 5$ GeV	
Electron energy spread		$\sigma_p = 9.5 \times 10^{-4}$	
Initial photon energy		$k_1 = 2.45$ eV	
Recoil parameter		$z = 0.188$	
Final photon energy		$k_M = 780$ MeV	
	ESRP	27/3	27/3 Mod
Horizontal emittance		$\varepsilon_x = 7.2 \times 10^{-9}$	15.2×10^{-9} m·rad

The present design, ESRP-27/3[4], consists of 32 periods composed of a long straight section followed by a short one.

The long straight sections are dispersion free and can be of two different types:

U) Undulator sections with 6 m free length, high β_x and therefore large beam dimensions and small angular divergences;
W) Wiggler sections with 3 m free length, low β_x, and therefore small beam size but large angular divergences.

The shorter straight section have a small dispersion of the order of 0.5 m, and will be indicated by D.

Following ref.(4), 1/16 of the machine can be represented by two half Undulator sections, two Dispersive sections and one Wiggler section. Therefore we have three possible choices of set-up:

D/2-W: the interaction region is located in a Dispersive section followed by a Wiggler section;
D/2-U: the interaction region is located in a Dispersive section followed by an Undulator section;
U/2-D: the interaction region is located in an Undulator section followed by a Dispersive section.

We find that the tagging detector should be located in the straight section after the first bending magnet so that it is not important which is the section after the second bending magnet. Moreover since the quadrupoles before the first bending magnet do not contribute to the dispersion of the system, the W/2-D set-up gives the same results of the U/2-D, and it is not important in which position of the straight section the electron-laser interaction takes place, since for all positions of the same straight section we have the same value from eq.(1).

In the first part of Table II we report the best theoretical values of the energy resolution (FWHM in MeV) at different location along the storage ring for a maximum gamma ray energy k_M=780 MeV with a machine energy E_0=5 GeV. As one can see placing the interaction region in a Dispersive section gives better results then placing it in an Undulator or Wiggler section.

In the second part of this Table we report the expected results in case of a machine modification studied by one of us[5]. This modification of a long straight section (A) and the adjoining Dispersive sections (D') will increase the horizontal emittance of the machine from 7.29×10^{-9} to 1.57×10^{-8} m.rad.

The results with this configuration (ESRP-27/3 Mod) indicated as A/2-D'-U/2 show that the best energy resolution (2.3 MeV) is obtained by placing the interaction region in the modified A section and the tagging detector inside the second bending magnet at the end of the Undulator section (code name position 107). This however is technically very difficult and therefore we have considered also position 100 and 114 which are located in regions with no magnetic fields just before and after the bending magnet. In particular position 100 appears very interesting since the scattered electrons arrive there at a distance of 8.6 cm from the main orbit and therefore we can detect them if we are able to modify only two quadrupoles and 5 meters of vacuum chamber. At this position the energy resolution is 3.9 MeV (FWHM) at 780 MeV, quite an exciting result and an improvement of almost a factor of three over the unmodified machine.

This calculations clearly indicate that the proposed 5 GeV ESRF machine appears a very exciting tool for the production of high resolution, fully polarized, monochromatic gamma ray beams in the energy range of 1 GeV. The energy of 780 MeV corresponds to a reduced wave length (λ=$=\lambda/2\pi$) of 0.25 fm. A spatial resolution which should allow to investigate the sub-nucleonic degrees of freedom of nuclei.

It is also important to note that while the results obtainable with the present design (Δk=10 MeV) are already very interesting, very exciting results (Δk=2-4 MeV) are in sight with some changes in the present version.

These results where obtained in the linear approximation and are to be checked with tracking programs, when the actual field distribution in quadrupoles and bending magnets will be known.

It is a pleasure to thank Prof. Sergio Tazzari for many usefull discussions.

TABLE II - TALADON project

European Synchrotron Radiation Facility - Gamma ray energy resolution

1 Set-up	2 Position	3 Component	4 L (m)	5 d (m)	6 σ_T (mm)	7 σ_T/d 10^{-4}	8 ΔX mm	9 Δk FWHM MeV
$\frac{D}{2}$ - W	51	1	8.2	0.35	0.36	10.2	5.4	12
	71	1	11.4	0.12	0.10	8.6	6.7	10
$\frac{D}{2}$ - U	51	1	8.2	0.33	0.33	10.2	5.1	12
	104	1	17.4	0.19	0.16	8.7	7.5	10
$\frac{U}{2}$ - D	58	1	9.6	0.32	0.42	12.9	5.1	15
		$\varepsilon_X = 1.57 \times 10^{-8}$ m·rad						
$\frac{A}{2}$ - D' - $\frac{A}{2}$	70	1	11.6	0.33	0.80	23.9	5.2	28.0
	100	1	16.6	0.55	0.18	3.3	8.6	3.9
	107	4	17.6	0.65	0.13	2.0	10.1	2.3
	114	1	18.6	0.79	0.20	2.5	12.3	3.0
$\frac{D'}{2}$ - A - $\frac{D'}{2}$	52	1	8.2	0.33	0.71	21.8	5.1	26.0
	97	1	16.3	0.88	0.68	7.7	13.6	9.0

Column	Name	Description
1	Set-up	indicates the position of the interaction region and the successive sections up to the location of the tagging detector;
2	Position	indicates the position of the tagging detector in the computer code we have used;
3	Component	indicates the magnetic component of the storage ring lattice at the selected location: 1 means a drift space and 4 a bending magnet;
4	L	is the distance in meters from the center of the interaction region to the selected position;
5	d	is the dispersion in meters calculated from the interaction region to the tagging detector;
6	σ_T	is the total radial spread of the beam at the position of the tagging detector;
7	σ_T/d	is the gamma ray energy resolution as a fraction of the electron energy given by eq.(1);
8	ΔX	is the maximum displacement from the main orbit of the scattered electrons before they reach the tagging detector;
9	Δk	is the gamma ray energy resolution (Full Width at Half Maximum) in MeV.

References:

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(5) M.Preger, Inserzione ad alta risoluzione energetica per il fascio gamma manocromatici sulla macchina europea per la luce di sincrotrone, LNF Internal Memorandum, n. G-56 (1985).