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Author

Selph, F

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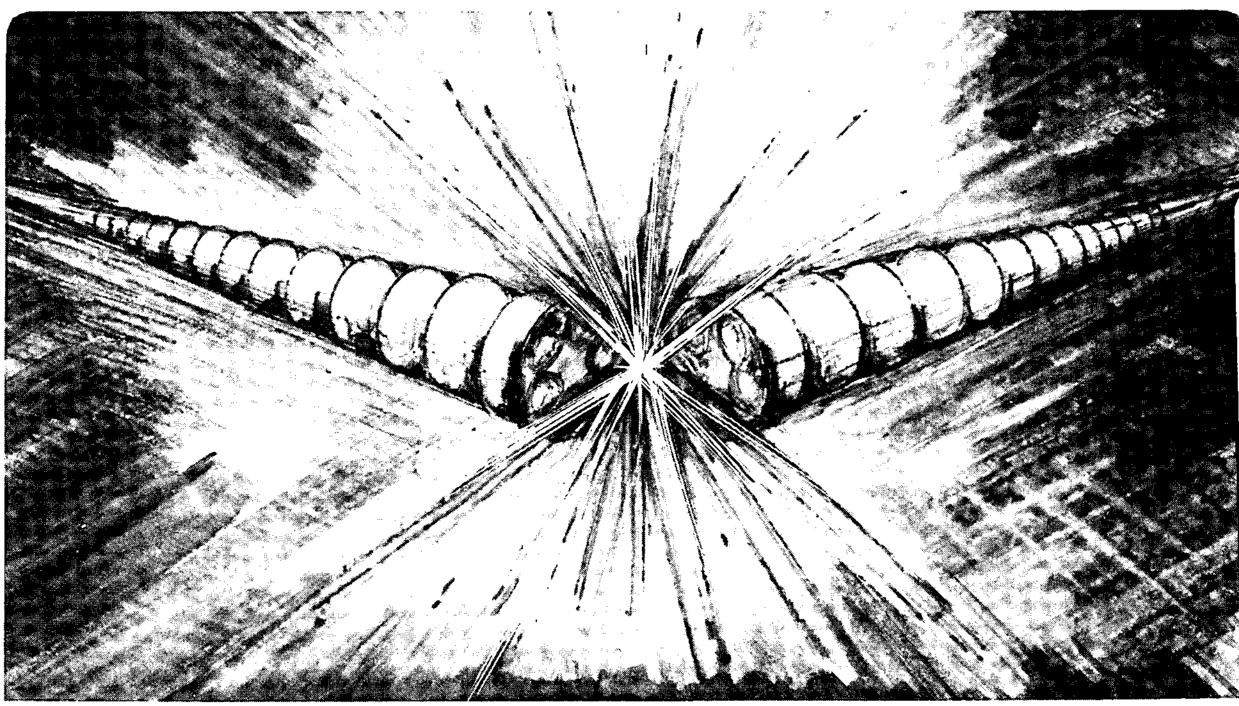

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Magnetic Ring for Stripping Enhancement*

Frank Selph

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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Frank Selph
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Introduction.

A ring designed to recycle ions through a stripping medium offers the possibility for increasing output of the desired charge state by up to 4x. This could be a very important component of a Radioactive Nuclear Beam Facility. In order for such a ring to work effectively it must satisfy certain design conditions. These include achromaticity at the stripper, a dispersed region for an extraction magnet, and a number of first and higher order optics constraints which are necessary to insure that the beam emittance is not degraded unduly by the ring. An example is given of a candidate design of a stripping ring.

Statement of the Problem.

To take an example of stripping, U ions at 1 Mev in a carbon foil yield 20% in the most abundant charge state, q=39. The 2σ spread in charge states is about 5 (1). If the most abundant charge state is extracted, and the rest are recycled through the stripper, after 10 turns we can expect about 90% of the injected beam to be extracted in the desired charge state (2). Although storage of a beam for ten turns is a trivial accomplishment for a storage ring, we shall see that this imposes stringent conditions in a stripping ring, in order to preserve beam quality.

The use of a stripping ring as an "enforcer" of the most abundant charge is an attractive idea, which has been studied by several authors (2,3,4). The main difference between this type of ring and a conventional storage ring is the need to accomodate very large momentum spreads - on the order of +/-15% if the full capability is to be realized. Designing a ring to accomodate such large momentum spreads is not a simple task. First-order storage ring optics can be used to arrive at a basic design concept, but then a careful study of higher order aberrations must be made.

Design Goals.

1. At the stripper location the ring must be dispersion free, or doubly achromatic, ie η_x and η_x' must be zero [η_x is defined by the relation $\Delta x = \eta_x(\Delta p/p)$]. This insures that, to first order, ions with different momentum will return to the same position at the stripper.
2. The value of η_x in one of the ring straight sections should be on the order of 1 m, so that an extraction magnet which operates only on the most abundant charge state can be located there. If η_x is much smaller, the installation of the extracion magnet will be difficult. If η_x is much larger, the required apertures in adjacent magnets (which must accept all charge states) will become unacceptably large.

3. The tune of the ring, both horizontal (ν_x) and vertical (ν_y) should be integral or half-integral. This is so that when the incoming beam is focused on a foil stripper (for example), the recirculating beam will remain focused on the same spot. The tolerance in the tune must be held to a fraction of 1%. If the tune varies from integral or half integral by more than this there will be considerable spreading, which will translate into emittance growth in the extracted beam. In a storage ring, integral and half-intergal tunes are avoided as any instability will be enhanced, leading to a beam blowup. In the stripping ring, as we expect ions will remain for only 10 revolutions at most, this will not be a problem.

4. A serious second-order effect which will degrade performance if it is not corrected, is due to the circumstance that quadrupoles focus particles with different momenta at different distances. In a ring this produces a tune shift as a function of momentum and is known as chromaticity, C_x or C_y, defined as:

$$C_{x,y} = \delta\nu_{x,y}/(\delta p/p).$$

For conservation of emittance both C_x and C_y should be zero. This will insure that the tune will be preserved for off-momentum particles.

Stripping Ring Design

As a minimum, the ring must have dipole magnets which bend through 360^o. Four 90^o magnets can make a compact ring, with edges providing vertical focusing, and quadrupoles to produce linear achromaticity, as shown in ref 4. To achieve the integral or half-integral tune, however, additional quadrupoles are required. This is necessary to allow some tuning range, as the focusing effect of fixed magnet edges cannot be predicted with sufficient precision. The quadrupoles used to produce dispersionless straight sections cannot be tuned.

Further, to correct the second order chromaticity requires two sets of sextupoles. They are only effective where there is dispersion in the ring. Dipole edges can be curved to provide a sextupole component, but to provide a tuning range some adjustable sextupole magnets will be necessary.

To illustrate these points, a candidate design for a stripping ring is shown in Fig. 1. Six 60^o dipoles are used. The beam rigidity , after stripping, is taken as 1 T-m. Of the six straight sections, 3 are achromatic and 3 have dispersion. The dispersion is controlled in each straight section by two quadrupoles (QSF). An extraction magnet is placed in one of the straight sections, where ν_x = 0.84 m. This magnet bends the beam vertically, so that in a downstream straight section it enters a vertical septum magnet where the beam is deflected so as to clear the dipole yoke. This two-magnet extraction scheme greatly reduces the strength required for the first extraction magnet, so that it can be more compact.

The tune of this ring is ν_x=2, ν_y=1. This tune is achieved primarily by the focusing action of the dipoles and the QSF quadrupoles. The additional quadrupole sets Q1 and Q2 are used to provide a tuning range.

One set of sextupoles is achieved by making the QSF quadrupoles also sextupoles. In fact, they would have two sets of windings so that the quadrupole and sextupole fields can be treated independently. This is simply to save space; it would be equally valid to place independent sextupole magnets adjacent to these quadrupoles. The other necessary set of sextupole corrections is made by curving the dipole edges adjacent to the dispersed regions, with some additional tuning range provided by poleface windings.

The stripper, which could be either foil or gas, is placed in one of the dispersionless straight sections. The injected incoming beam is taken into the ring through the yoke of a dipole, at an angle so that after stripping it has the proper ring orbit. The extracted beam is shown exiting the ring by being guided over the yoke of this magnet. There are other possibilities for the extraction arrangement, depending on the overall facility layout.

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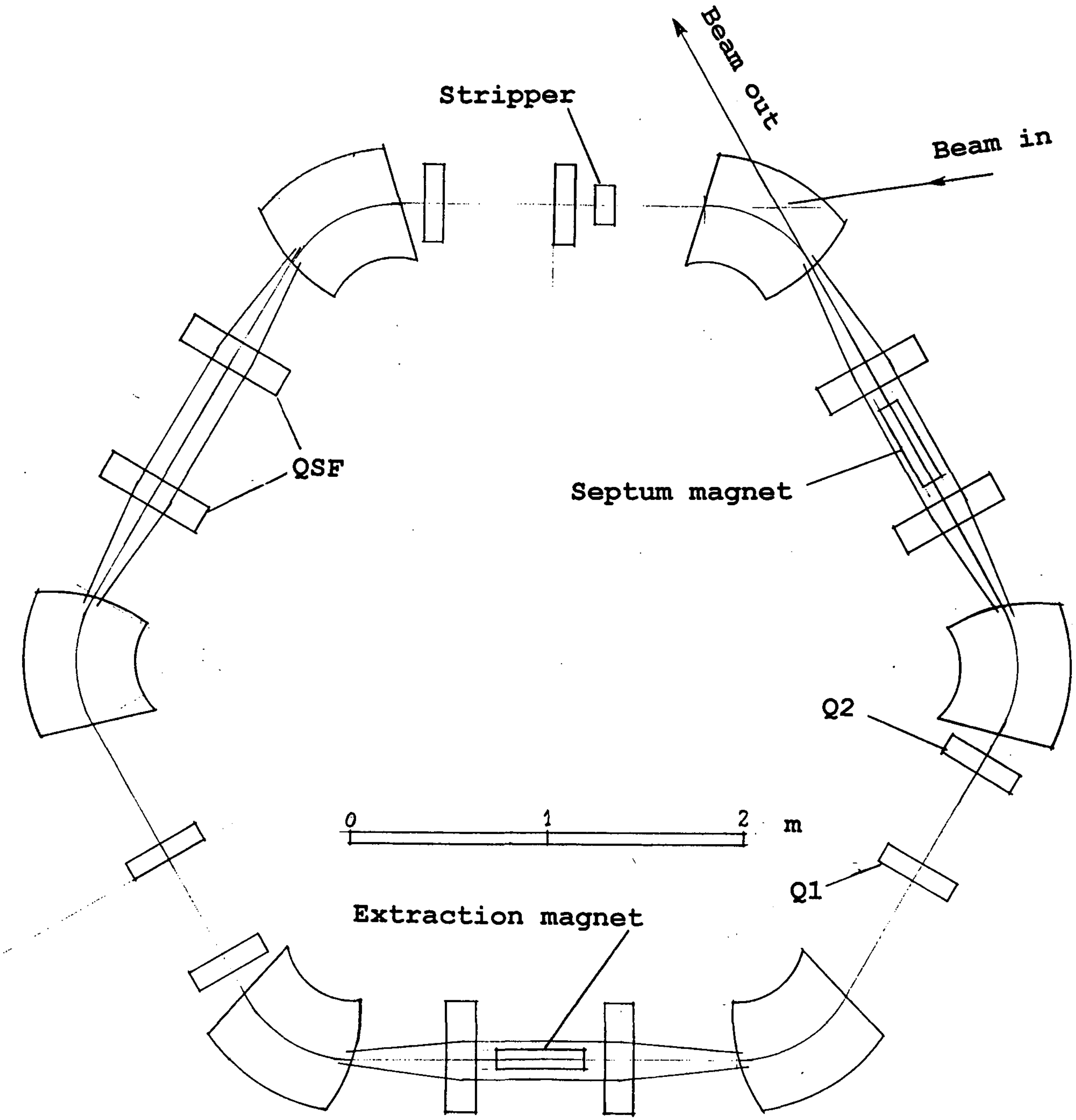

Fig.1 Ring for enhancing output of stripper

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720