Nuclear Instruments and Methods in Physics Research A 830 (2016) 88–94

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Dispersion in closed, off-axis orbit bumps

R. Apsimon [a,b,*], J. Esberg [c], H. Owen [b,d]

[a] The University of Lancaster, Lancaster LA1 4YW, United Kingdom
[b] The Cockcroft Institute, Sci-Tech Daresbury, Daresbury, Warrington, United Kingdom
[c] CERN, Meyrin, Switzerland
[d] The University of Manchester, Manchester M13 9PL, United Kingdom

ARTICLE INFO

Article history:
Received 28 January 2016
Received in revised form
14 May 2016
Accepted 18 May 2016
Available online 20 May 2016

Keywords:
Dispersion
Orbit bump
Off-axis
Beam dynamics

ABSTRACT

In this paper we present a proof to show that there exists no system of linear or nonlinear optics which can simultaneously close multiple local orbit bumps and dispersion through a single beam transport region. The second combiner ring in the CLIC drive beam recombination system, CR2, is used as an example of where such conditions are necessary. We determine the properties of a lattice which is capable of closing the local orbit bumps and dispersion and show that all resulting solutions are either unphysical or trivial.

1. Introduction

Typical local orbit bumps in beam transport systems vary on the timescale of 0.1–100 s and therefore may use conventional dipole magnets. Faster orbit bumps can be achieved with the use of kicker magnets which may operate on timescales from 10 ns up to 100 ms. Such systems can be designed to correct the dispersion function either side of the local orbit bump with relative ease. For some applications, such as the injection into the second combiner ring CR2 for the CLIC drive beam recombination system, multiple local orbit bumps are required on sub-nanosecond timescales; thus RF deflectors are required rather than conventional dipole magnets or kicker magnets.

The CLIC drive beam requires 2×24 pulses, each consisting of 2904 bunches with a bunch spacing of 82 ps. To achieve this, the CLIC drive beam linac produces 24×24 sub-pulses with a bunch spacing of 2 ns. A recombination system is used to interleave bunches over 3 stages to produce the required pulse trains (Fig. 1). Further details of this system can be found in [1].

The second combiner ring stores bunch trains for up to 3.5 turns; on each turn an additional bunch train is injected such that the bunches are interleaved with the stored bunches. The principle of the injection scheme is depicted in Fig. 2; as is shown, there are two stored trajectories and the injection trajectory passing at the same time through the injection region. In order to avoid beam losses at the injection septum magnet a bump amplitude of ~3 cm is required and to interleave bunches with a bunch spacing of 82 ps (12 GHz) a 3 GHz RF deflector is required with the bunches 90° apart in RF phase.

A conventional orbit bump can be achieved with the use of 4 deflectors to create a dispersion-free 4-bump (Fig. 3). A deflecting cavity has been designed at SLAC [2] which is similar to the design which would be required by CLIC to achieve a 3 GHz RF 4-bump. The SLAC deflecting cavity has a frequency of 2.815 GHz and an iris radius of 2.2 cm ($\sim 0.2\lambda$); the CLIC CR2 RF deflectors would require a frequency of 3 GHz and an iris radius of ~4 cm ($\sim 0.4\lambda$).

However, the orbit bumps in the injection region might also be closed with two RF deflectors and a lattice of multipoles (such as quadrupoles) as depicted in Fig. 4. CLIC has opted to investigate this design scheme for the CR1 and CR2 injection regions [1] and it is this scheme which is investigated in this report.

If the beam centroid were to travel on-axis through the quadrupole, this lattice would be a double-bend achromat and would be dispersion-free. However, the dipole term introduced by traveling off-axis through the quadrupole gives a contribution to the dispersion which prevents the dispersion closing through the lattice. As will be shown, there exists no system of linear or nonlinear optics between the RF deflectors which can simultaneously correct both the dispersion and the orbit bump.

If there were only one trajectory through the CR2 injection region, a dispersion suppression region could be placed downstream of the injection region to compensate the residual dispersion from

* Corresponding author.
E-mail address: r.apsimon@lancaster.ac.uk (R. Apsimon).

http://dx.doi.org/10.1016/j.nima.2016.05.074
0168-9002/

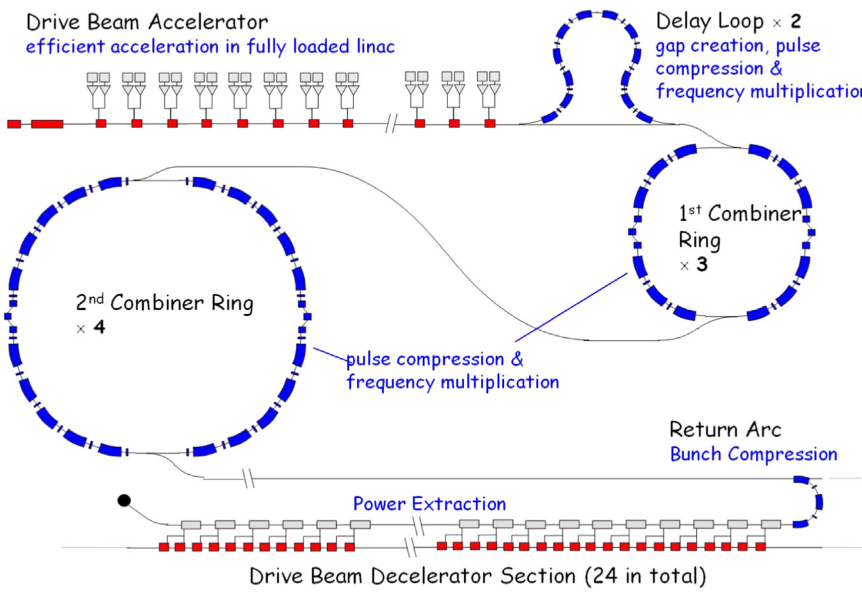

Fig. 1. A schematic diagram of the CLIC drive beam recombination system [1].

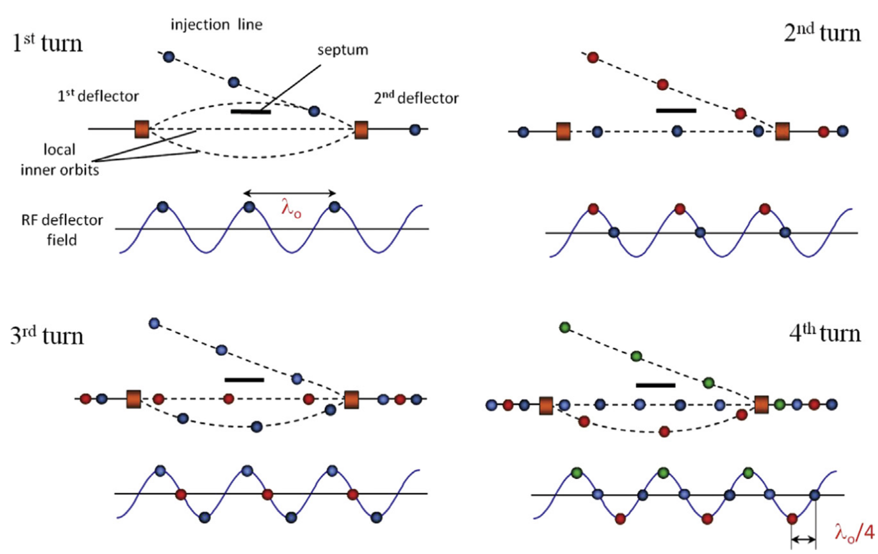

Fig. 2. A schematic diagram to show how the combiner ring injection region interleaves bunches over 4 turns [1]. On each turn the stored bunches take different trajectories.

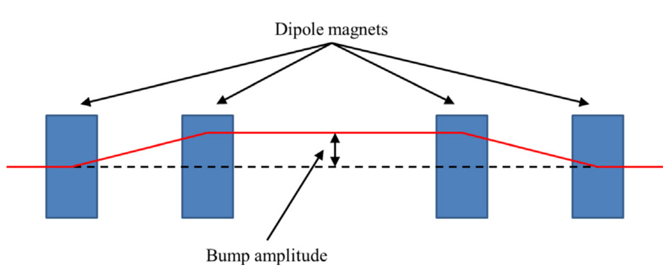

Fig. 3. A schematic diagram of a 4-bump.

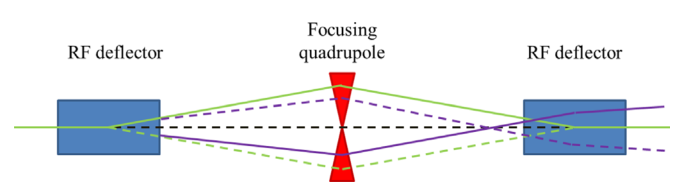

Fig. 4. A schematic diagram of a local orbit bump (green) and dispersion (purple) with two RF deflectors and a single focusing quadrupole. The solid and dashed green lines show equal and opposite amplitude orbit bumps through the injection region. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the injection region. However, as there are multiple simultaneous trajectories through the injection region, each trajectory will give rise to different residual dispersion; thus a dispersion suppressor would not be able to simultaneously correct the dispersion for all trajectories.

In Section 2 of this paper, we show that if a lattice exists which can create a dispersion-free closed orbit bump then a symmetric lattice can be designed which can also create a dispersion-free closed orbit bump. By considering the central region of an arbitrary symmetric lattice, we determine the general conditions under which a dispersion-free closed orbit bump can be achieved. In Section 3 we define equations for the residual dispersion from the quadrupoles due to the off-axis trajectory of the beam and use this to define specific conditions on the lattice parameters for a dispersion-free closed orbit bump to exist. In Section 4 we investigate the specific conditions under which a dispersion-free closed orbit