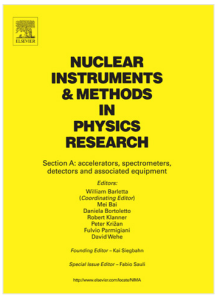
Accepted Manuscript



Photocathode laser based bunch shaping for high transformer ratio plasma wakefield acceleration

G. Loisch, J. Good, M. Gross, H. Huck, I. Isaev, M. Krasilnikov, O. Lishilin, A. Oppelt, Y. Renier, F. Stephan, R. Brinkmann, F. Grüner, I. Will

PII: S0168-9002(18)30197-9
DOI: https://doi.org/10.1016/j.nima.2018.02.043
Reference: NIMA 60572

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date : 30 October 2017
Revised date : 8 February 2018
Accepted date : 9 February 2018

Please cite this article as: G. Loisch, J. Good, M. Gross, H. Huck, I. Isaev, M. Krasilnikov, O. Lishilin, A. Oppelt, Y. Renier, F. Stephan, R. Brinkmann, F. Grüner, I. Will, Photocathode laser based bunch shaping for high transformer ratio plasma wakefield acceleration, *Nuclear Inst. and Methods in Physics Research, A* (2018), https://doi.org/10.1016/j.nima.2018.02.043

Photocathode laser based bunch shaping for high transformer ratio plasma wakefield acceleration

G. Loisch, J. Good, M. Gross, H. Huck, I. Isaev, M. Krasilnikov, O. Lishilin, A. Oppelt, Y. Renier[1], F. Stephan

Deutsches Elektronen Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

R. Brinkmann

Deutsches Elektronen Synchrotron DESY, Notkestrasse 85, 22607 Hamburg, Germany

F. Grüner

Center for Free-Electron Laser Science and Universität Hamburg, 22607 Hamburg, Germany

I. Will

Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Max-Born-Str. 2a, 12489 Berlin, Germany

Abstract

Beam driven plasma acceleration is one of the most promising candidates for future compact particle accelerator technologies. In this scheme a particle bunch drives a wake in a plasma medium. The fields inside of the wake can be used to accelerate a trailing witness bunch. To maximise the ratio between acceleration of the witness to deceleration of the drive bunch, the so called transformer ratio, several methods have been proposed. The ones yielding the most favorable results are based on shaped drive bunches that are long in terms of the plasma wavelength. We present here methods to create such drive bunches employing temporally shaped UV-laser pulses for the extraction of electron bunches from a photo-electron gun. Theoretical considerations, experimental results and possibilities for further improvements are discussed.

Keywords: Bunch shaping, Wakefield acceleration, Photoinjector, Transformer Ratio

1. Introduction

Since the first proposal of particle acceleration in plasma wakes driven by intense, relativistic particle bunches (PWFA) [1] much theoretical and experimental work has been done to build a compact accelerator based on this scheme. Even though many aspects of beam driven plasma acceleration have already been demonstrated in experiments, like acceleration with gradients exceeding conventional ones by several orders of magnitude [2] or high efficiency acceleration [3], several other aspects are still only theoretically explored. One of these aspects of PWFA is the achievement of a high transformer ratio (TR), which is the ratio between the highest accelerating field along the witness bunch and the highest decelerating field inside of the drive bunch.

In linear wakefield theory the TR was shown to be limited to below 2 in case of symmetric drive bunches by the so-called fundamental theorem of beamloading [4]. Theoretical investigations on how to improve this ratio have already started shortly after the proposal of the PWFA [5] and different methods have been worked out, either relying on shaped drive bunches [5, 6, 7] or on multiple drive bunches of different charge densities [8, 9]. For all these scenarios, as well as for other applications in wakefield based accelerators, like flattening of inhomogeneous accelerating fields by the witness bunch shape via beamloading [10], flexible beam shaping capabilities are crucial. So far the availability of such beam shaping techniques has limited the possibilities for experimental investigation of these aspects of plasma acceleration.

In the following we will present a technique on how to create shaped electron bunches with a high flexibility in the exact shape and without modifications of the accelerator beamline, by shaping the UV pulse of a photoinjector. The technique is demonstrated experimentally, possible optimisation considerations are discussed and finally the method is compared to other bunch shaping techniques.

2. Šolc fan filter cathode laser pulse shaping

Electron beams for wakefield acceleration are usually supplied by photoinjectors, as only these electron sources

Email address: gregor.loisch@desy.de (G. Loisch)
[1]now at DPNC-Université de Genève, 24 Quai Ernest Ansermet, Geneva, Switzerland