Memorandum of Understanding

Between
Name of Party: Wigner Research Centre for Physics of the Hungarian Academy of Sciences (WRCP)
Address: Konkoly-Thege Miklós út 29–33, H-1121, Budapest, XII.
Contact Person: Prof. Dr. Péter József Lévai

and
Name of Party: The Max Planck Institute for Physics (MPI)
Address: Fröhringer Ring 6, 80805 München, Deutschland
Contact Person: Prof. Dr. Allen Caldwell

We, the Wigner Research Centre for Physics of the Hungarian Academy of Sciences and the Max Planck Institute for Physics (Werner Heisenberg Institute) have to come together to make an agreement for a scientific cooperation. The partners entering the MoU have agreed a form of collaboration and so agree to the following articles and clauses.

Purpose and Scope

In order to start a collaboration the WRCP will develop an effective method for creating an extremely homogenous Rb plasma in an extended volume and investigate its physical properties with experimental and theoretical means.

Background

This document is strongly based on the former MoU which was signed by Patric Muggli, György Vesztergombi and Aladár Czitrovszky in Budapest on the 6th February 2013.
The main tasks to clarify were:

- identification of different ionisation processes in Rb,
- determination of the laser pulse energy/intensity needed for (800 +/- 40) nm wavelenght ultra short (< 100fs) laser pulse.

Goals and Objectives

The WRCP gained a valuable experience on how to create Rb gas and Rb plasmas. Our vision is that with application of ultra-short chirped laser pulses via resonant excitations the total 100 percent single-ionisation of the Rb gas can be achieved much more efficiently than from the ground state [1]. The statement that an excited Rb state can be 100 percent populated via chirped laser pulses has been experimentally and theorticaly proved by our group [2].
In the last year we built a small and compact Rb gas cell and investigated the photo-ionisation properties of the Rb. Recently we found that the 35 fs ultra-short laser pulse with 800 nm mean wavelength causes a single-photon resonant excitation and the two-photon ionisation process was clearly verified. Some part of these results were presented at the last AWAKE meeting at CERN 10.04.2014.
After these successful pre-studies we began to build up an extended plasma cell with a length of 75 cm. The experimental setup is under construction and will be ready this autumn. A new

laboratory room is also under construction for this larger equipment. Optical elements, mirrors, lenses, chopper, shutter and other electronic elements are at hand.
Our aim is to repeat our former experiment, identify the resonance-enhanced two-photon ionisation and investigate the homogeneity of the plasma at the same time.
Our extended resonance chamber has got a special geometry which makes it possible to perform various plasma diagnostics during the ionisation process.
This long plasma cell can be illuminated from the side with independent laser beams coming from a tunable diode laser at different distances measuring the absorption of the laser beam. Therefore the homogenity of the plasma can be investigated in a direct way.
As a second method based on luminescence the homogenity can be investigated as well.

For the theoretical investigation we had and have the following activity. Mr. Mihály Pocsai developed a numerical method in his Master Thesis which was capable to calculate the acceleration of an electron in an underdense plasma. This description is based on classical electrodynamical calculations including an effective index of refraction of the plasma. He found that the behaviour of the electron in an underdense plasma only slightly differs from the vacuum case. These results were presented on the AWAKE meeting at CERN at 10.04.2014 and on the poster section of the ECLIM 2014 conference in Paris this September as well.
Mr. Mihály Pocsai is a first-year PhD Student in our institute, his research field is to build up a model and calculate the ionisation processes of a single Rb atom in the electromagnetic field of a simultaneous short laser pulse [3] and a fast proton [4]. The idea is to develop an atomic physical approach mixed with some quantum optical elements. After this first step a propagation model will be developed in order to investigate the ionisation processes that take place in a Rb vapour with a spatial extent. Similar models still exist but only for quantum systems with low number of excited states and without any contribution from the ionisation.
If the distribution of the electric filed is known in the cell, as a final step the acceleration of the electrons can be calculated as well. To our knowledge there is no such a model available in the plasma physics which involves atomic physical contributions. We hope that this model will help us to study new and exotic features of the AWAKE Rb plasma and will give informations beyond the PIC simulation results.
Mr. Mihály Pocsai has got at least three years for the development of such a complex model which is comparable in time with the whole CERN AWAKE experiment and development.
Two of our young colleagues, Mr. Mihály Pocsai and Mr. Károly Varga-Umbrich—both PhD students—are going to attend the CERN

Accelerator School on Plasma Wake Acceleration

this November.

The WRCP claims that the technical details and the experiences learned from the investigation will be transferred to the MPI when asked.
The WRCP contact person of the cooperation is going to attend all the regular meetings which are asked.

Literature

[1] M. ALADI, J.S. BAKOS *et al.*, Nucl. Instr. Meth. in Physics Res. A, **740**, (2014) 203
[2] G.P. DJOTYAN, J.S. BAKOS, *et al.*, Phys.Rev. A, **68** (2003) 053409
[3] I. F. BARNA AND J. M. ROST, Eur. Phys. J. D, **27**, (2003) 287
[4] I. F. BARNA, N. GRÜN and W. SCHEID, Eur. Phys. J. D, **25**, (2003) 239

Authorization

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