Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant ☐

(please tick the relevant box)

Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online within one month of the event. It should not exceed eight A4 pages.

Proposal Title: Demonstration of a novel single-shot ultrafast diagnostic based on the dispersion-scan technique using sub-4 fs laser pulses.

Application Reference N°: Short Visit Grant 5585

1) Purpose of the visit

The purpose of the visit to the lab of Helder Crespo in Porto was to test the design of a single-shot ultrashort pulse diagnostic. The basic principle comes from the dispersion-scan (D-scan) technique[1], where the frequency doubled spectrum of the pulse to be characterised is measured as a function of dispersion. This is achieved by inserting different amounts of glass in the pulse before the second harmonic generation. Once the 2-D information dispersion/spectrum is known, an algorithm can retrieve the pulse under investigation.

D-scan is of simple implementation, requiring only a standard 1-D spectrometer, and a stage to insert a different amount of glass at each measurement. However it is inherently not suitable for a single-shot measurement. To overcome this limitation a new experimental design has been developed at Imperial College London, to allow the measurement to be taken in the single-shot regime. For a single-shot measurement the data taken at each laser shot has to be the same as the one required by the D-scan algorithm, i.e. two-dimensional. For this reason an imaging spectrometer has been used, where it is possible to measure the pulse spectrum as a function of spatial position. The remaining step is to map the dispersion scan onto the position axis on the spectrometer.

[1] M. Miranda, T. Fordell, C. Arnold, A. L'Huillier, and H. Crespo, "Simultaneous compression and characterization of ultrashort laser pulses using chirped mirrors and glass wedges," Opt. Express **20**, 688-697 (2012).

To achieve this goal a prism has been inserted in the beam, so that different spatial parts of the beam experience a different dispersion.

Figure 1 shows the schematics of the developed design. The image of the beam after the prism was then imaged twice, once on the Second Harmonic Generation (SHG) crystal and once more on the spectrometer entrance. The development of this design has been carried out at Imperial College London, and the purpose of the visit was to have a direct comparison between the standard D-scan setup already available in Porto, and the new single-shot setup.

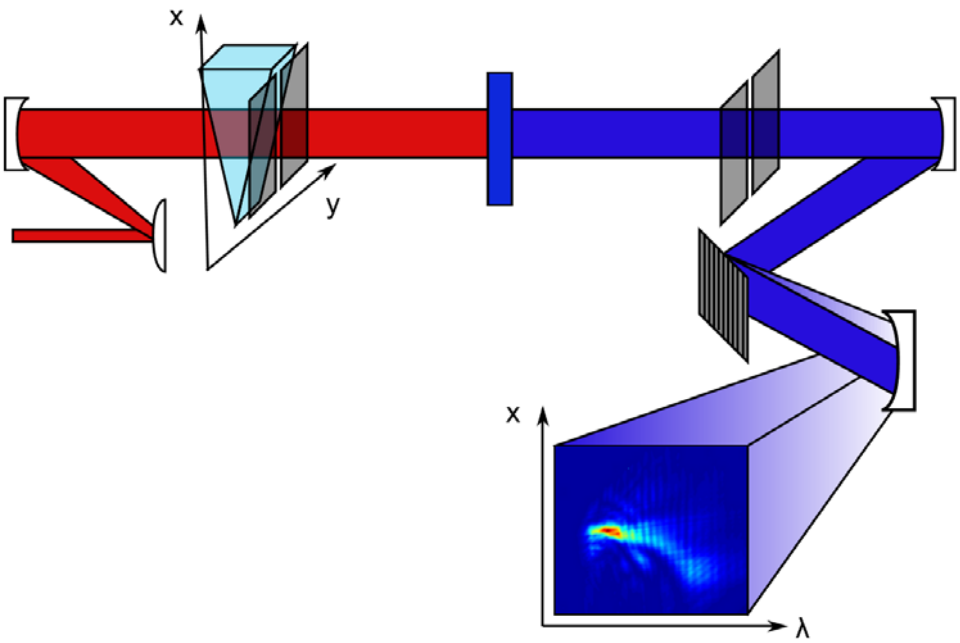

Figure 1: Schematic of the single shot setup. A prism induces the required dispersion in different spatial positions of the beam. An imaging spectrometer measure the second harmonic spectrum as a function of such position.

2) Description of the work carried out during the visit

The single-shot D-scan experiment was planned to be carried out in one intensive week.

Day 1: First day was devoted to unpacking and installation of the equipment brought from London.

Day 2: In the second day the setup was prepared and a first alignment was done. This day was also dedicated to install on the Porto computer the software necessary for the communication between the camera included in the imaging spectrometer and the computer.

Day 3: During the third day the alignment was optimised and a preliminary result was obtained. However, the signal obtained was too low to be analysed.

Days 4 and 5: These two days were used to systematically improve the setup and, which finally allowed good quality data to be obtained. The main obstacle that had to be faced was the low signal to noise ratio on the camera. For this reason the focusing system was modified to obtain higher intensity in the SHG crystal and therefore achieve a higher signal on the camera. In addition, we reduced the aberration of the system by using smaller angles and by replacing two mirrors to have a better reflectivity at lower wavelengths.

Day 6: The last day of this campaign was used to measure the single-shot D-scan trace under the best conditions we managed to achieve. As we were able to obtain a standard D-scan trace in a parallel setup we could check the single-shot data against the trace from the standard configuration.

3) Description of the main results obtained

This Porto campaign was conceived with the objective of measuring a D-scan trace using a single-shot method in order to validate and demonstrate this new technique. This method relies on mapping in a single-shot the dispersion to spatial position across the beam profile, using a dispersive element (prism). An imaging spectrometer is used to spatially resolve the spectrum allowing the d-scan data to be recorded.

This experimental campaign was a success, since its main objective of demonstrating in a proof-of-principle experiment single-shot capablity was achieved. The D-scan trace comparison is shown in Figure 2, where we can see the similarities between the results obtained using both techniques. Next step is to use a retrieval algorithm to characterize the optical pulse and make a more detailed evaluation.

In short, single-shot technique works as expected and seems to be acceptable to characterize an ultrashort laser pulse.

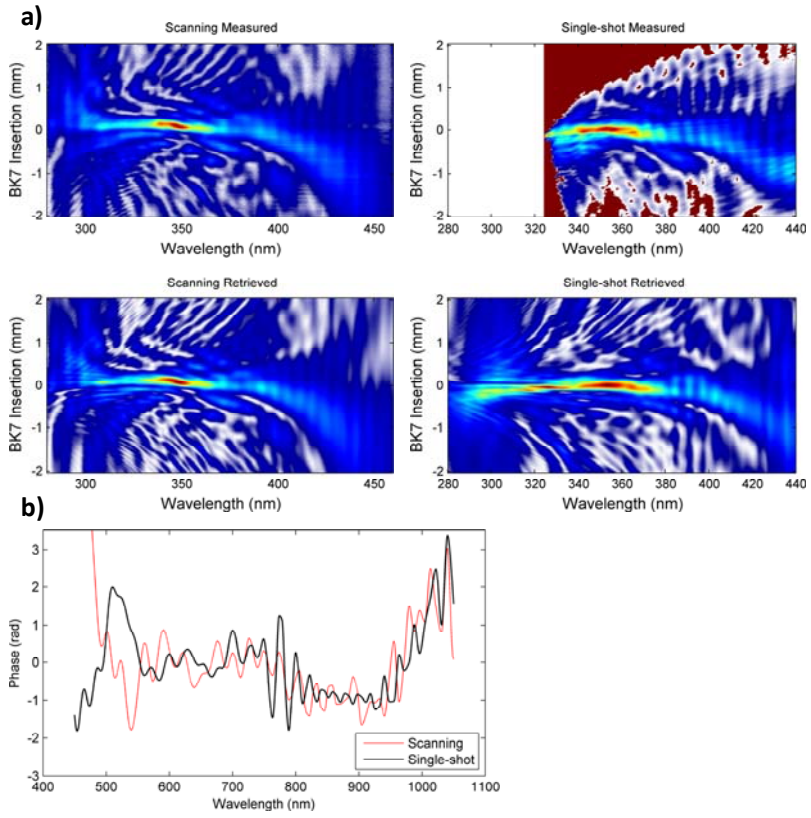

Figure 2: a) Comparison of scanning ("standard") d-scan [left hand column] and the new single-shot method [right hand column]. The top row is the measured 2D data, the second row is the 2D retrieval.
b) The retrieved phase for both techniques, showing good overall agreement.

4) Future collaboration with host institution (if applicable)

We anticipate future collaboration between the Imperial College and Porto groups. For example, we are considering a campaign at Imperial College to compare d-scan (possibly including its new single-shot realisation) against another short-pulse diagnostic (SEA-F-SPIDER) in the sub 4 fs few-cycle regime. The goal would be to measure and thus compensate any residual dispersion on the few-cycle pulse, e.g. using additional propagation in a bulk dispersive material to compensate residual third order dispersion.

One member of the team involved in the present work (Mr Warein Holgado) is from the Salamanca group. Mr Holgado spent several months in the end of 2013 working in the Imperial College London labs where he spent much of his time developing the optical set up for the single-shot d-scan. He then participated in the campaign in Porto. Future collaboration is planned between the Salamanca and Porto groups, building on previous successful joint work In the future, this collaboration will be reinforced by the development of a new ultrashort laboratory in Salamanca with the aim of performing research in the few-cycle regime. As the Porto group has wide knowledge of this field, joint experiments will be done.

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

We believe this single-shot implementation will be of interest to other ultrafast laser groups. We hope to publish the results in an high profile optics journal, such as Optics Letters or Optics Express within a few months.

6) Other comments (if any)

We are grateful for the financial support from the ESF.