Table top femtosecond x-ray source for time resolved x-ray diffraction experiments

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Abstract

Advanced synchrotron radiation techniques are being developed to obtain refined analysis in materials science. One particular case of studies is devoted to obtain time resolved information using the sub-nanosecond x-ray pulses from bunches of the synchrotron storage ring allowing to probe picosecond dynamics of systems in multidisciplinary areas. Interesting applications within biological systems are the dynamics of the isomerized cis-trans conformation of rhodopsin found in human eyes, or the structural dynamics of myoglobin by the photo-excitation of carbon monoxide. Unfortunately interesting phenomena is found in the sup-picosecond time scales not available for synchrotron techniques. An interesting complementary tool is the use of a table top laser based femtosecond x-ray sources being developed worldwide. At UNICAMP we have developed a prototype of this source where x-ray pulses are produced by the interaction of 1 mJ, 60 fs near infrared pulses focused at a titanium tape target at 1 kHz repetition rate. The control system, the mechanical and electronic setup was developed in our laboratory and the first x-ray production tests were performed at the Quantum Electronics Department. The source characterization as well as its first use for time resolved x-ray diffraction studies will be presented.

Key words:

Femtosecond, x-rays, diffraction.

Introduction

This project began with old members of LCARX (Laboratory of Applied Crystallography and X-Rays), they worked developing an ultra short pulsed X-ray table top source, called Femto by the group. This machine allows the execution of time resolved experiments of multidisciplinary areas of knowledge on a small laboratory table, instead of a big synchrotron laboratory. The first Femto was just a small vacuum box with a titanium target inside it and two windows, one of kapton and the other of glass. A high density power femtosecond pulsed laser was focused in a point of the titanium target. The high temperature in this point creates a momentary plasma, causing high kinetic energy particles to interact with titanium atoms producing X-rays.

The actual Femto is a cylindrical vacuum chamber, which inside it, there is a parabolic gold mirror, a debrie protector to prevent that deposit of particles of plasma on the mirror, and the head with two reel that contains titanium tape used as target.

The main focus of this work is to provide a fully function and ready to use table top source of femtosecond pulsed x-rays, which means to deal with control system techniques in order to control all the elements of the system. Above all, this control needs to refresh the titanium tape before laser has destroyed it and make sure that laser will interact with cooled and solid part of the material in each pulse. Beyond the refreshing target system, the project involves laser alignment and focusing, control the debrie protector, the position of the mirror and the detection of the X-rays.

Results and Discussion

The mechanical system was modified to keep the tangential velocity of the refreshing system constant. The

DC motor controller used to refresh the tape was bought from Germany (PI C863 controller) and the other motors used are stepper motors, and its drivers are manufactured by SETHI in Brazil.

The circuits and cables from the controllers to motors and to the computer were manufacture on LCARX, by George. Above all, the computational routine of the source was written in Python language. The computer communicates with controllers via serial RS-232 protocol, sending commands that moves the motors in way to generate X-rays.

All optics has been set after the participation of George some experiments in CLA (Laser and Applications Center).

The X-ray generated from the source is being characterized using APD (Avalanche Photodiode) and Amptek X-ray detectors.

Conclusions

All mechanical, electrical and computational systems are working well. Optics is well aligned in order that it generates plasma on titanium target. The source is able to produce X-rays and we are characterizing the properties of the X-rays generated.

Acknowledgment

I want to thank professor Carlos Giles for all orientation, professor Lazaro Padilha for giving the laser to use on this project and Ricardo Samad for the training with lasers.

¹ Perman, B. *Science* **1998**, 279, 1946-1950.

² Strajer, V. *Science* **1996**, 274, 1726.

³ Rousse, A. *Phys. Rev.* **1994**, 50, 2200.