3 Euratom fusion programme

3.1 Integrated Tokamak Modelling

Tokamak modelling: participation in the work of ITM-IMP3 task force

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Abstract

The aims of ITM project is to developed the system of codes covering the all task. involved in full modeling of the tokamak. The particular codes are considered as the modules implemented as the actors in KEPLER system. The particle codes communicate between themselves by the defined pieces of information so CPO (Consistent Physical Object). Basic part of the system is ETS (European Transport Solver) solving the transport equations for densities, temperatures, toroidal rotations for all bulk ions and plasma current. The separate part of the system is ITS (Impurities Transport Solver) solving the transport equations for impurities. The work on numerical problems involved in ETS and ITS and as implementation of some improvements into KEPLER are presented in the report.

Introduction

The tests of ETS shows that the algorithms used do not satisfied the conservation of energy and particles. New algorithm has been developed satisfying the conservation laws and implemented into ETS. The possible modification of algorithms for stiff transport, characterized by strong nonlinear dependence of the transport coefficients on the gradients of the solutions, are analyzed.. In this case the numerical oscillation of the solution appear. This oscillation can be avoided only for practically unreasonable small time step. The program ITS has been tested by comparing the results of ETS/ITS with the results of codes Sanco/Jetto. New module describing of the transport of neutrals in the core has been developed and implemented into KEPLER workflows.

New algorithms satisfying conservation laws

In ETS all transport are in general form. The transport equations are solved on normalized interval (0,1).

$$\frac{a(t+\Delta t)y(t+\Delta t)-a(t)y(t)}{\Delta t}+\frac{\partial}{\partial r}\left(-d\frac{\partial y}{\partial r}+ey\right)=aS$$

$$\frac{a_{i+1/2}(t+\Delta t)y_{i+1/2}-a_{i+1/2}(t)y(t)_{i+1/2}}{\Delta t}\Delta r+\Phi_{i+1}-\Phi_i=S_{i+1/2}a_{i+1/2}\Delta r$$

The interval is divided into subinterval with space step h. We look for the values of the solution in the middle of subintervals. Two additional ghost mesh points are introduced r=-h/2 and r=1+h/2. The discrete equation can be written in the form.

The boundary conditions are imposed at the points r=0 and r=1.

$$\Phi_i = -1/2d_i \frac{y_{i+1/2} - y_{i-1/2}}{\Delta r} + 1/2(e_{i+1/2}y_{i+1/2} + e_{i-1/2}y_{i-1/2})$$

$$\Phi_0 = -d_0 \frac{y(h/2) - y(-h/2)}{h} + e_0 \frac{y(h/2) + y(-h/2)}{2} = 0$$

$$V\frac{\partial y}{\partial r} + Uy|_{r=1} = W = V\frac{y(1+h/2) - y(1-h/2)}{h} + U\frac{y(1+h/2) + y(1-h/2)}{2}$$

The summation of the discrete equations shows that the algorithms satisfied the conservation low. The numerical tests shows that the scheme has second order of convergence with respect of the space grid size h. The algorithm was implemented for nonuniform mesh and included into ETS.

Stiff transport problem

The analyses of method of adding additional diffusivity to transport equation has been performed. The consists of adding to diffusion coefficient the extra large term in order to reduce the numerical oscillation. To compensate the error introduce by increase of the diffusion coefficient the same diffusion term but calculated for the solution from previous time step as follows:

$$\frac{a(t+\Delta t)y(t+\Delta t) - a(t)y(t)}{\Delta t} + \frac{\partial}{\partial r}\left(-(d + d_{add})\frac{\partial y}{\partial r} + Vy\right) = aS - \frac{\partial}{\partial r} d_{add} \frac{\partial y(t-\Delta t)}{\partial r}$$

$$D_{an} = \begin{cases} D_0 + D_1(|y'| - y'_{cr})/|y'|, & |y'| > y'_{cr} \\ D_0 & |y'| < y'_{cr} \end{cases}$$

In order to have deep insight to the behavior of the solution the simple analytical models of the diffusion mocking the properties of typical properties of the stiff transport model e.g. GLF23 (Gyro Landau fluid) The results are presented as an example for the following diffusion model:

For stiff problem for sufficiently small time step the numerical instability in form of oscillations disappears. The Fig.1 shows that even for time step 10^{-4} the oscillation still exists. With extra diffusion term the oscillation disappear even for time step 10^{-2} as shown onfFig. 2.

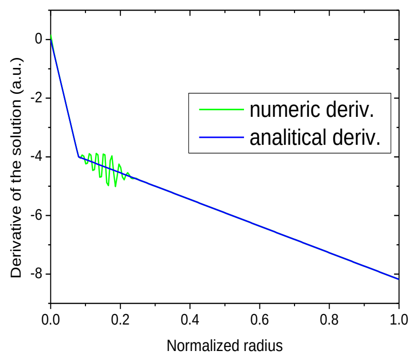

Fig. 1. Solution without the extra diffusion term

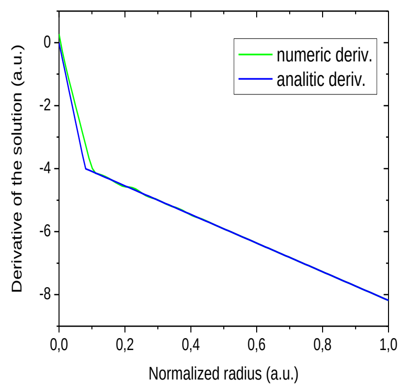

Fig. 2. Solution with extra diffusion term

The presented example was chosen for simple case for which the analytical solution can find. Fig. 2 shown that the error introduced by extra diffusion term in this case is negligible. In practical calculation the detection of oscillation should be automatic and control of the error caused by the method of mitigation of oscillation imposed. The following procedure has been tested.

Detection of the oscillation can be based on the number of extremal points of the solution defined by the expression $(y_{i+1}-y_i)(y_i-y_{i-1})<0$. As the measure of the error can be taken the sum of the extra term introduced in the transport equation. Appearing of oscillation should caused the increase of the extra diffusion coefficients and the error exceeding the assumed tolerance should follow by reduction of time step. This approach has been tested for simple diffusion model and it was find that proper tuning the parameter deciding of modifying the extra diffusion term and time step leads to reasonable good results. The method will be tested on physical model of stiff transport in the next year.

Testing ITS

The module ITS has been tested for various impurity. Comparison of the results of the ETS/ITS and Jetto/Sanco shows very good agreement. The results of comparison are show as an example for Argon.

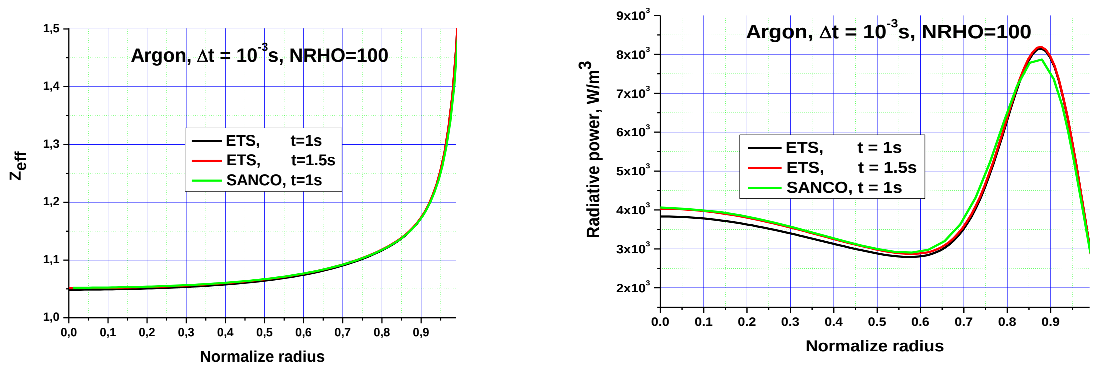

Fig. 3. Comparison of Z_{eff} and radiative power

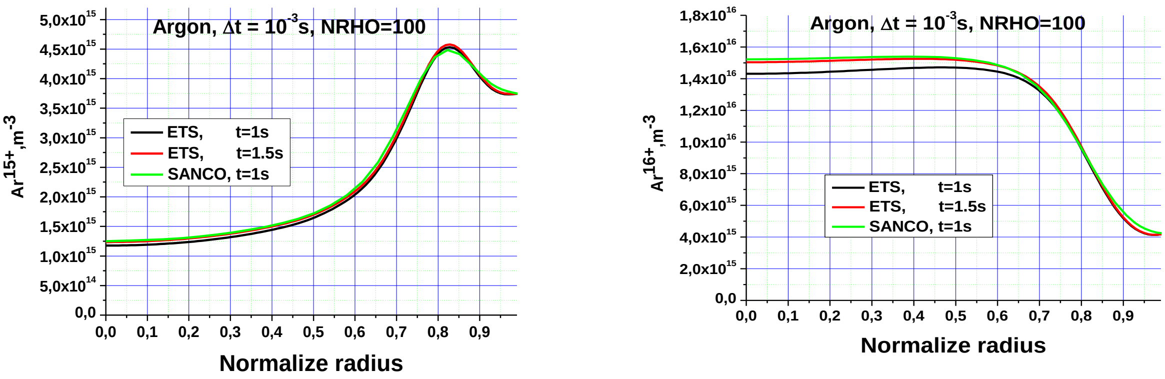

Fig. 4. Comparison of density profile for some ionization state for ARGON

Module describing transport of impurities in the core

The new module for neutrals in the core has been developed. The transport of neutrals is described by diffusion equations with diffusion coefficient defined by mean free path. The processes of ionization, recombination and charge exchange have been taken into account. The neutrals for main ions and for impurity ions have been considered. The two energy group for neutrals has been introduced. The slow neutrals born in scrape of layer corresponding to characteristic temperature in the edge. The fast neutrals with higher energy born inn the charge exchange processes in the core. Due to the that slow neutrals density can reached only small distance from separatrix its energy corresponds to some characteristic temperature in layer closed to separatrix. The module automatically use the atomic data from ADAS data library. The KEPLER actor was generated and implemented in KEPLER workflow. The results of some test are presented on fig. 5.

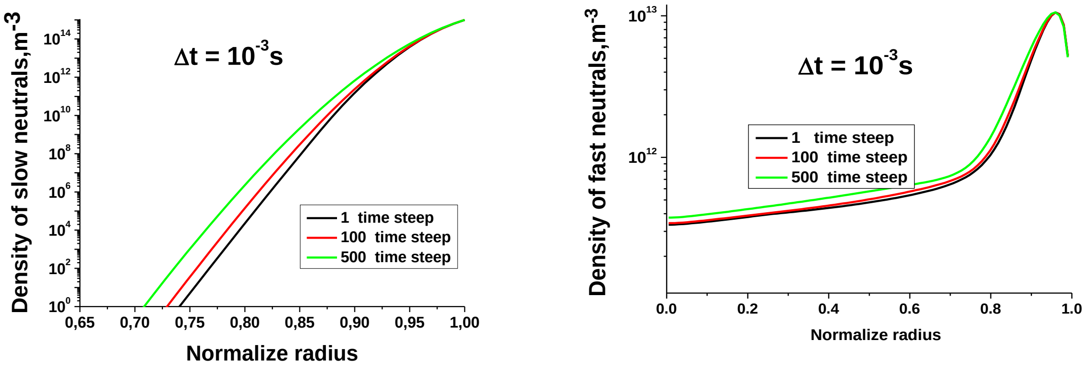

Fig. 5. Example of profiles for slow and fast neutrals

Conclusion

The testing of ETS and ITS has been performed. and weakness of the algorithms used in ETS detected. New algorithm for solving transport equation has been developed. .The new module for neutrals transport has been developed and implemented on KEPLER platform.

Preliminary analysis of baseline DEMO concepts

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Abstract

Two scenario pulsed and steady state for Demo reactors has been analysed using code COREDIV. The intensity of Argon seeding has been increased until the steady state does not exists due to excessive radiation or plasma dilution. It was shown that for steady scenario the power to target plate can be reduced with the increasing of Argon concentration to acceptable level. But it turns out the radiated power remains almost constant but dilution of plasma by impurities reduced the alpha power and in consequence the power load to the plate. Reduction of the power load to plate reduced the self-sputtering of Tungsten but the sputtering of Tungsten by Argon increased with the Argon concentration. As the results the concentration of Tungsten remains constant. Since Tungsten radiates more then 90% of the whole radiation the radiated power become constant. For pulsed scenario the concentration of Tungsten even in absence of Argon is closed to point below which the solution does not exists.

Introduction

The reduction of divertor target power loads to an acceptable level is a critical issue for future fusion reactors. The radiative exhaust of energy by sputtered and by externally seeded impurities is considered as possible way of spreading energy over wall area.

This paper describes integrated numerical modelling for the first time applied to DEMO discharges with tungsten wall and argon seeding using the COREDIV code [1,2]. Since the energy balance depends strongly on the coupling between the bulk and the scrape-off layer plasma, modelling requires the transport problem to be addressed in both regions simultaneously. The COREDIV code self-consistently solves radial 1D energy and particle transport equations of plasma and impurities in the core region and 2D multifluid transport in the SOL. The model is fully self-consistent with respect to both the effects of impurities on the α-power level and the interaction between seeded and intrinsic impurities. This interaction leads to a significant change in the intrinsic impurity fluxes, and it is found to be essential for a correct evaluation of the average power to the target plates. The code has been successfully benchmarked with the nitrogen seeded type I and type III ELMy H-mode discharges on JET [3,4] and with ASDEX discharges in the full W environment [5].

Model used in the code COREDIV

In the core, the 1D radial transport equations for bulk ions, for each ionization state of impurity ions and for the electron and common ion temperature are solved. With respect to the energy sources, alpha heating is calculated self-consistently with the plasma dynamics, whereas for auxiliary heating parabolic-like deposition profile is assumed. The energy losses are determined by bremsstrahlung, synchrotron and line radiation. The electron and ion energy fluxes are defined by the local transport model which reproduces a prescribed energy confinement law. The anomalous heat diffusivity is given by the formula $\chi_{ei} = C_{ei}\ F(r)(a^2/\tau_E)$, where r is the radial coordinate, a is the plasma radius, τ_E is the energy confinement time defined by the ELMy H-mode scaling law, a is the plasma radius and the coefficients $2Ce$,$=Ci$, are adjusted to have agreement between calculated and experimental confinement times. The profile function F(r) is chosen to provide transport barrier in the boundary of the plasma. The main plasma ion density is given by the solution of the radial diffusion equation with diffusion coefficients De = Di = 0.35 χ_e and small anomalous pinch term Vi=Di = $0.1r/a^2$ to avoid W accumulation in the core.

In the SOL, we use the 2D boundary layer code EPIT which is primarily based on Braginskii-like equations. An analytical description of the neutrals allows the inclusion of plasma recycling as well as the sputtering processes at the target plates. We assume that the divertor is in attached (semi-attached) mode and the hydrogen as well as the impurity recycling coefficients are external parameters. A simple slab geometry (poloidal and radial directions) with classical parallel transport and anomalous radial transport is used and the impurity fluxes and radiation losses caused by intrinsic and seeded impurity ions are calculated fully self-consistently. We solve the equations only from the midplane to the target plate assuming inner-outer symmetry of the problem.

The coupling between the core and the SOL is done by imposing continuity of energy and particle fluxes as well as of particle densities and temperatures at the separatrix.

Results

We have considered inductive DEMO scenario (Pulsed) and DEMO Steady-State configuration with tungsten walls and Ar seeding. The following parameters have been assumed for Steady-State scenario: R_T =8.5m, a = 2.83m, elongation k = 1.66, I_p=18 MA, B_T=5.74 T, $\langle n_e \rangle = 0.91\times10^{20}\mathrm{m}^{-3}$, confinement factor H_{98} = 1.3, and P_{aux} = 200 MW, whereas for Pulsed DEMO we have been used: (R_T =9.6m, a =2.4m, k =1.66, I_p = 23 MA, B_T = 7.45 T, $\langle n_e \rangle = 1\times10^{20}\mathrm{m}^{-3}$, H_{98} = 1.2, P_{aux} = 100 MW).

The recycling coefficient was iterated to have the prescribe plasma density at the separatrix ($n_{es}=1/3\langle n_e \rangle$).

The main results for both scenario are shown on Fig. 1 and Fig. 2.

In steady state scenario the reduction of power load can be reduced to acceptable level. But the Q parameter is significantly reduced due to reduction of alpha power. The profile for radiative losses in the core for all impurities is presented on Fig.3. for the case of the Argon concentration similar to Tungsten concentration. The results shows that Argon radiation is negligible. With the increase of the argon concentration, surprisingly the radiation level remains almost constant Fig.4 which is the result of the interplay between the energy losses and tungsten source due to sputtering processes. Indeed, increased argon influx and radiation in the SOL lead to the reduction of the plasma temperature at the target and consequently to the reduction of the self-sputtering yield, leaving total tungsten concentration almost unchanged. Fig. 5

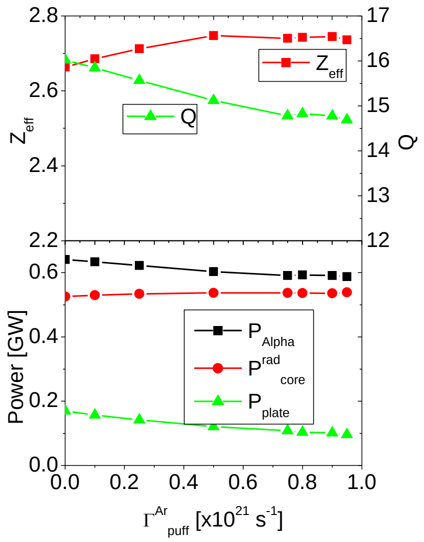

Fig.1. Plasma parameters for H&CD. Pulsed scenario

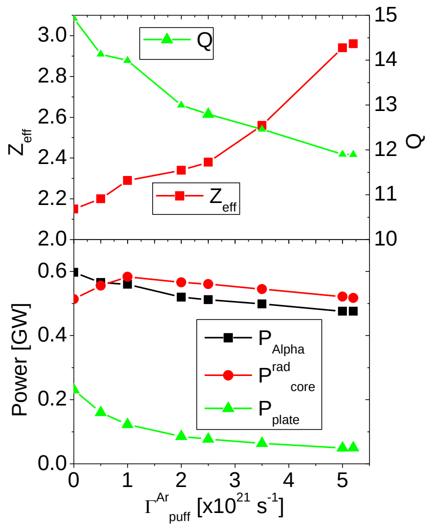

Fig. 2. Plasma parameters for H&CD. Steady state scenario

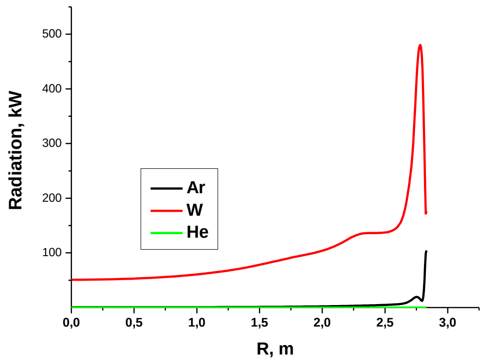

Fig. 3. Radiation profile for steady state

In pulsed scenario it has been found that in this case the helium accumulation might be a serious problem. Even without seeding the resulting Zeff is very large (>2.6) and consequently fuel density is low, at the level of the ion density for DEMO Steady scenario for which the solution terminates. Therefore, only relatively weak seeding can be applied for pulsed scenario, which does not lead to significant changes of main plasma parameters. It should be noted that the effect of helium accumulation is more serious if major radius increases, for RT> 10.5 m (other parameters not changed) steady state solution with burning plasma does not exist. It is obvious that the presented results depend strongly on the transport model used for helium, if the helium diffusion is increased than the steady state solution is recovered again, even with much higher Q factor.

Conclusions

In case of steady state scenario the power load to plate can reduced to acceptable level. Reduction has been achieves by reduction of the alpha power due to dilution of plasma by increase of Argon concentration. The Argon radiation is negligible but increasing Argon sputtering plays the essential role in keeping the almost constant concentration of Tungsten despite reduction of Tungsten selfsputtering due decrease of power load to target plate.
In case of pulsed scenario the concentration of helium is very high even in absence of Argon, Only limited seeding of is possible without breaking the discharge.

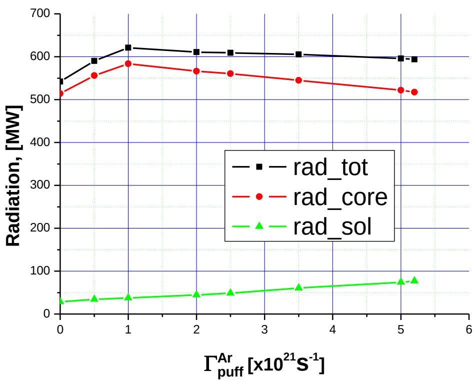

Fig. 4. Radiative power for steady state

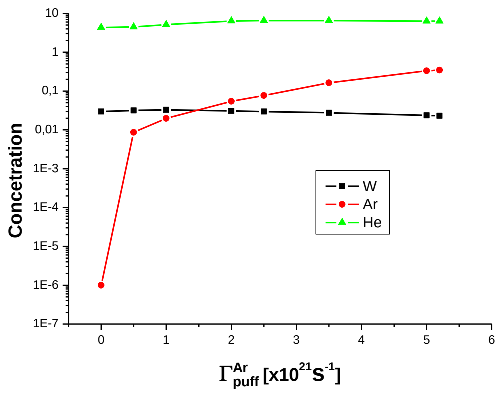

Fig. 5 Concentration of W, Ar and He for steady state

References

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[5] R.Zagórski, et al., *Integrated Modelling of ASDEX Upgrade Nitrogen Seeded Discharges,* presented at 13th International Workshop on Plasma Edge Theory in Fusion Devices, 19-21 September, 2011.

3.2 Plasma-Wall Interaction

Study of laser based diagnostic methods, photonic cleaning and spectroscopy (including LIBS) in perspective of next-step fusion devices (including ITER); Spectroscopic and ion diagnostics for laser-induced removal of fuel and co-deposits from PFCs in tokamaks

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Abstract

The work included activities in the area of the following EFDA-PWI tasks:

- WP11-PWI-02-03-01/IPPLM/BS – Photonic Cleaning Methods
- WP11-PWI-02-06-01/IPPLM/BS – Conversion of co-deposits to dust
- WP11-DIA-02-02-01/02 Development of a FFT based model to interpret the measurements under vibrations by identifying the mechanical vibrations (of few tenth of mm amplitude and of hundreds of Hz to KHz range) from the erosion measurements
- WP11-ETS-DTM-01-05-01 Qualification of the LIBS operation on ITER relevant calibrated samples.

The research in 2011 was mainly focused on optimization of the removal method with the use of a fiber laser. It was imposed by the possibility of obtaining clean removal process i.e. such that does not damage the bulk substrate and does not produce dust. Elimination of dust is especially important as it allows to avoid fuel accumulation inside the dust particles. This feature was extremely difficult to obtain in the case of application of the Nd:YAG laser with high energy and high power density pulses. This research has been conducted in framework of the task WP11-PWI-02-03-01.

Another task was investigation of dust production which included task WP11-PWI-02-06-01. This research relied on taking images of the dust released from Textor limiter sample which was covered with a thick co-deposit layer. As the irradiation source an Nd:YAG laser system was applied which delivered 3.5 ns, up to 0.6 J laser pulses at the wavelength of 1.064 µm. The images were taken by a high resolution fast CCD camera with resolution of 2048x2048 pixels.

A separate part of the task was aimed on qualification of the LIBS operation on ITER relevant material samples. This part included investigation of calibrated samples in order to assess the possibility of measurements of fuel inventory in in-vessel reactor components.

A different task was a development of a FFT based model to interpret the measurements under vibrations by identifying the mechanical vibrations (of few tenth of mm amplitude and of hundreds of Hz to KHz range) from the erosion measurements. It considered finding possibilities of digital signal processing for speckle interferometry which in the previous year was proposed as a candidate method for erosion measurements in the ITER divertor.

Introduction

Removal of the in-vessel deposited layers by the means of both laser desorption or ablation is a candidate method for dealing with fuel retention in next step tokamak devices. In addition to the efficiency of the removal process, two important issues are avoiding the release of fuel containing dust and avoiding the damage to the bulk substrate material. The previous research at the IPPLM has show that, however, laser ablation method can lead to complete removal of the codeposited layer, but the dust release is unavoidable and the risk of the bulk damage is relatively high. In contrary, the method which uses the application of a fiber laser which provides lower peak power density of the laser irradiation and basis rather on sublimation than ablation can be expected not to damage the substrate and not to produce dust.

In order to verify this thesis, research has been conducted at the IPPLM. In the experiments the thresholds for removal of the layers and substrate have been estimated and the effects of the removal have been tested by the means of optical profilometry.

The experiments with conversion of co-deposits to dust were performed by the high resolution fast CCD camera observation of particles released from the TEXTOR limiter sample by means of laser irradiation by intense pulses of ~0.6 J and ~3.5 ns focused to the spot of approximately 2-3 mm.

The measurements which were aimed at qualification of LIBS as a technique for measurements of fuel inventory in the next-step devices were performed on some calibrated samples covered with DLC and mixed material (W:Al:C) layers contaminated with various amounts of deuterium which were provided by collaborating laboratories also involved in this task.

The task on identification of the signal processing method for speckle interferometry was not an experimental task and it was oriented on the literature study and implementation of a preliminary algorithms.

Experimental set-up

All the experimental tasks were performed in a common set-up which was an effect of the evolution of a system which was useful for earlier research in previous years. The set-up is presented in fig. 1.

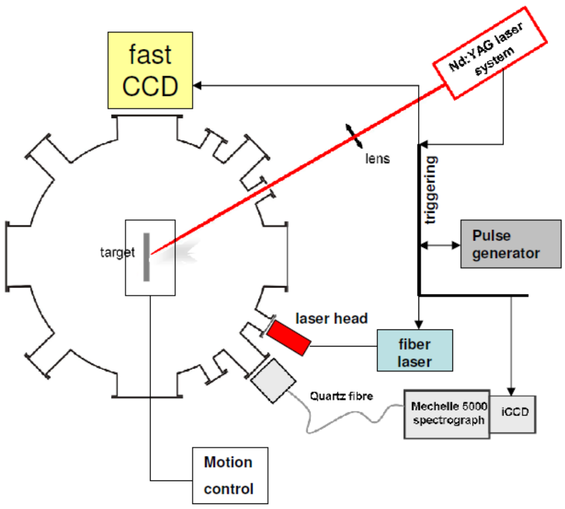

Fig. 1. The experimental setup

In this set-up a sample was installed in a vacuum chamber on a remotely controlled movable holder. The pressure in the chamber may be lowered to values in range of 10^{-5} Torr as well as it can be set at an arbitrary value for a mix of gasses provided by two micrometric valves. Both laser systems (Nd:YAG and Yb:fiber) and diagnostics (Mechelle spectrometer and the CCD camera) were incorporated into one system with common triggering by the pulse generator. Nd:YAG laser provided ~3.5 ns pulses up to 0.6 J at 1.064 μm, Yb:fiber laser up to 1mJ pulses of 100 ns at up to 100 kHz (which gaves an average power of up to 100W). The spectral resolution ($\lambda/\Delta\lambda$) of the spectrometer was 4000 (4 pixels FWHM), wavelength accuracy less than $\pm$0.05 nm and total insertion delay of 35 ns. The area of observation of laser-induced plasma was a circle of diameter of ~5 mm distanced ~3 mm from the target. The measured spectral signals were recorded and processed by the means of Andor Solis software. A CCD camera allowed for recording single frames or series of frames of duration down to 10 μs with spatial resolution of 2048x2048 pixels. The source of triggering was the Nd:YAG laser which triggered the pulse generator which then triggered other devices. The delay of the spectrometer was set-up for values in range from 50-500 ns depending on the aim of the experiment.

Results

The investigation on the layer removal with the fiber laser was began with the assessment of the threshold for removal of the graphite substrate. This threshold was considered to be the lowest among the thresholds for removal of all ITER relevant substrates and not exceeding it should guarantee avoiding damage to any substrate material. The research consisted on the irradiating a carbon substrate by the Yb:fiber laser with subsequently decreasing power density. The change of the power density was achievable by the change of the energy of the laser pulses in range from 1 mJ down to 0.1 mJ. The irradiation were performed in single spots on the substrate for a given time (20 s). The laser induced craters have been characterized by means of optical profilometry. Sample 3D maps of the craters corresponding to specified pulse energy and power density are shown in fig. 2.

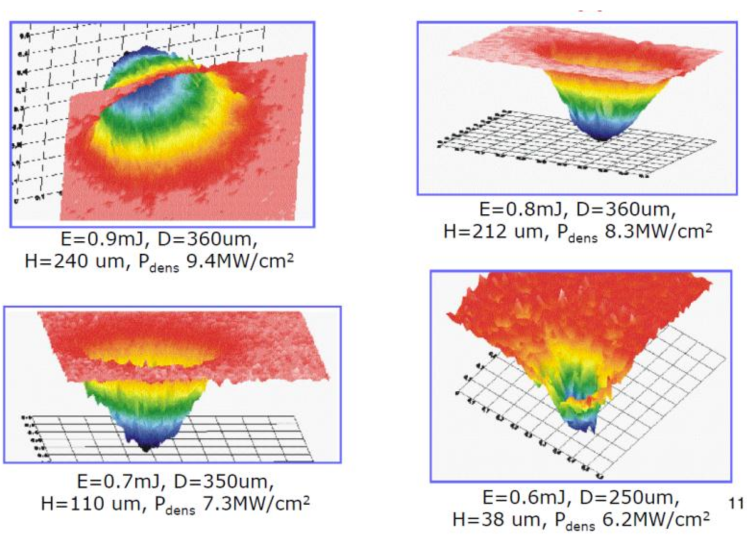

Fig. 2. A 3D maps of laser induced craters

Based on the crater parameters measured by the profilometry, volumes of the craters have been calculated and put on the graph which is shown in fig. 3. The crater volume depended linearly on the power density and the threshold of removal has been estimated as 6 MW/cm^2.

Similar experiment was performed with decreasing laser fluence controlled by the repetition rate, but it did not show any threshold for removal in terms of the total laser fluence, so it was assessed that the obtained threshold value for power density is the one which should be applied in the next experiments with removal.

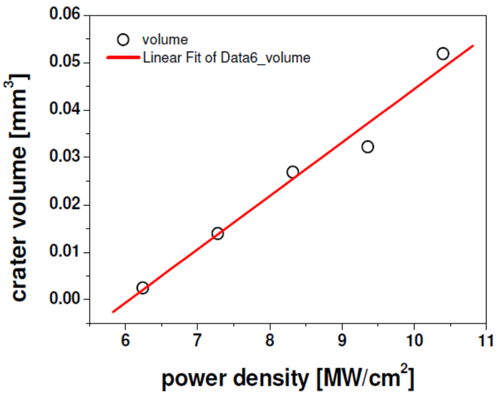

Fig. 3. Crater volume in dependence of power density

The next experiment was to investigate the removal of mixed material layers from aluminum substrate with the use of a laser beam of power density lower than the threshold estimated in the previous experiment. The experiment was performed in two steps: first was a single point irradiation and the second was irradiation by means of the scanning beam. The single point irradiation was performed for two spots with 10 s and 1 s duration respectively. Effects of the laser irradiation was then measured by the means of profilometry. The results are presented in fig. 4.

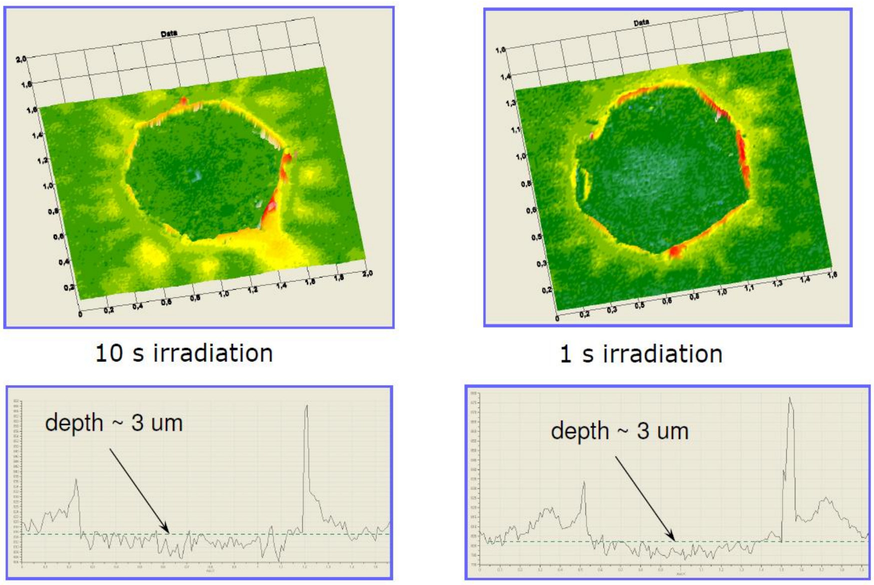

Fig. 4. A 3D profilometry maps and single profiles taken for W:Al:C samples for 1 and 10 s irradiations

As it can be seen in fig. 4, the depth of the craters did not increase regardless of the one order increase in the irradiation. It is the proof that the threshold for the substrate removal is not exceeded while the whole layer in both cases was removed.

The next step of the research was to test the removal with the scanning beam. A few velocities were tested and gave good results in terms of removal. Some sample results are presented in fig. 5.

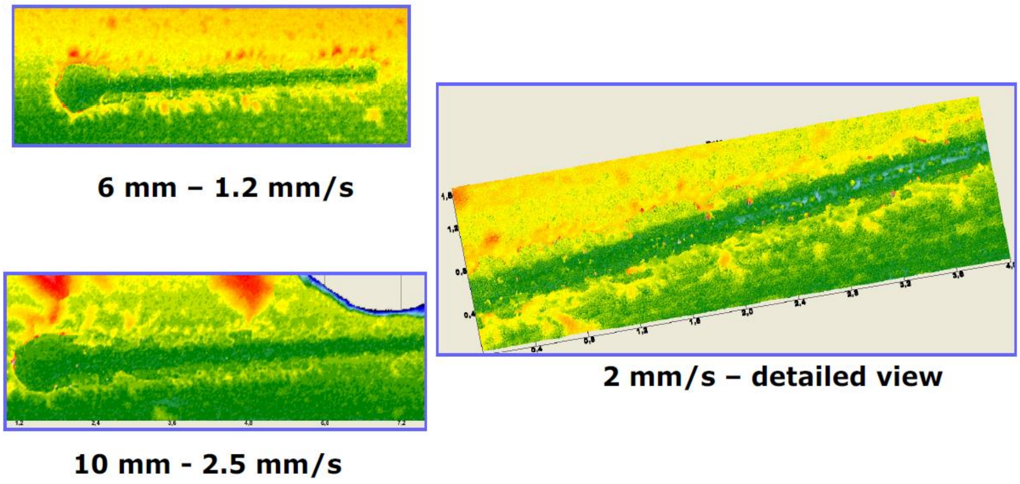

Fig. 5. A 3D profilometry maps of laser induced tracks with W:Al:C layer removed from Al substrates

In the experiments on characterization of film break-up processes it was observed that dust emission was starting approximately 40 μs after a laser pulse and lasted for a relatively long time reaching even more than a half of millisecond (up to 700 μs). During this time a stable amount of particles could be observed. In reactive gases atmosphere the comet effect was observed. The velocity of the dust particles was estimated in the range of one hundred m/s in vacuum and down to 30 m/s in the reactive gasses atmosphere. Sample images taken 40μs after laser pulse for 10 and 100 μs acquisition time are presented in fig. 6.

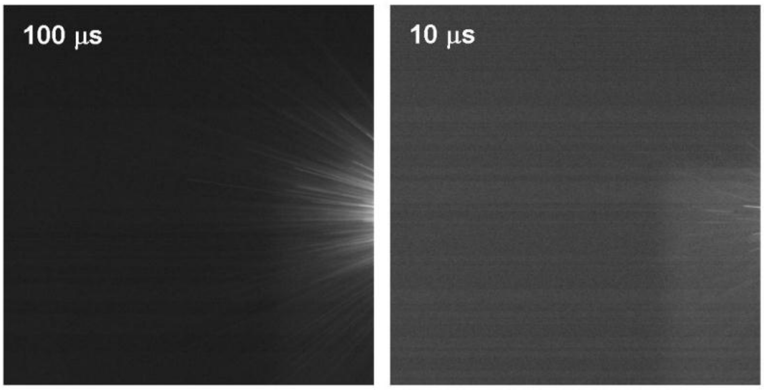

Fig. 6. Sample images of dust release due to ns laser pulse for 10 and 100 μs time frame. The pictures were taken 40 μs after laser pulse. The target was located on the right side

Most of the work in framework of qualification of the LIBS operation on ITER relevant calibrated samples, due to the delays with preparation of the samples were postponed for year 2012. Nevertheless up to the date some samples with DLC coatings were investigated and consistent results were obtained. The difference in the deuterium contents between the samples was arguable to be detected by means of a direct measurement of the Dα line intensity but it was measurable by means of comparison of Dα and some strong carbon lines. Preliminary results are presented in fig. 7.

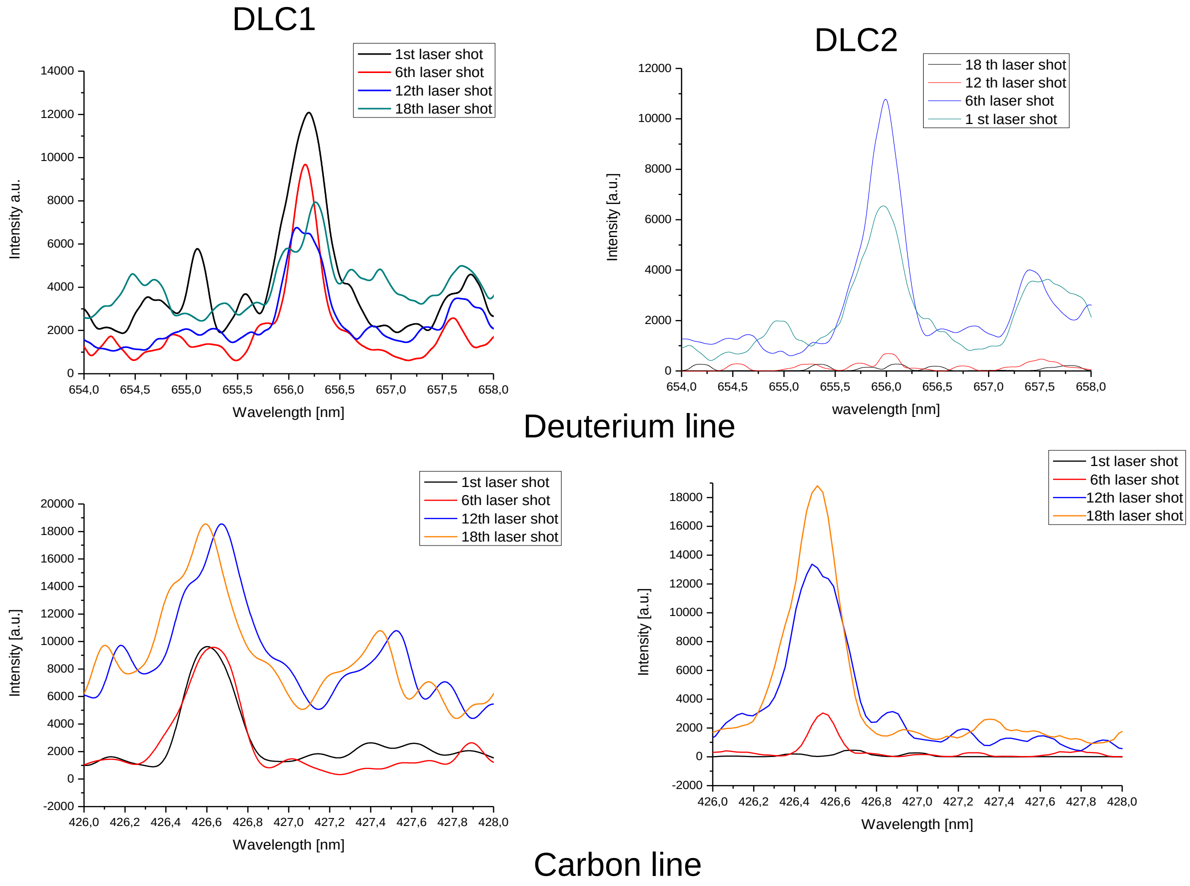

Fig. 7. D-alpha (656.2 nm) and CII 426.7nm lines registered for callibrated DLC samples

The study on the development of the signal processing algorithms for analysis of the speckle interferometry for the next-step fusion devices in vibrational environments led to conclusion that the operation of removal of the harmonic components of vibration can be implemented by means of application of a digital FIR (Finite Impulse Response) which scheme is shown in Fig. 8.

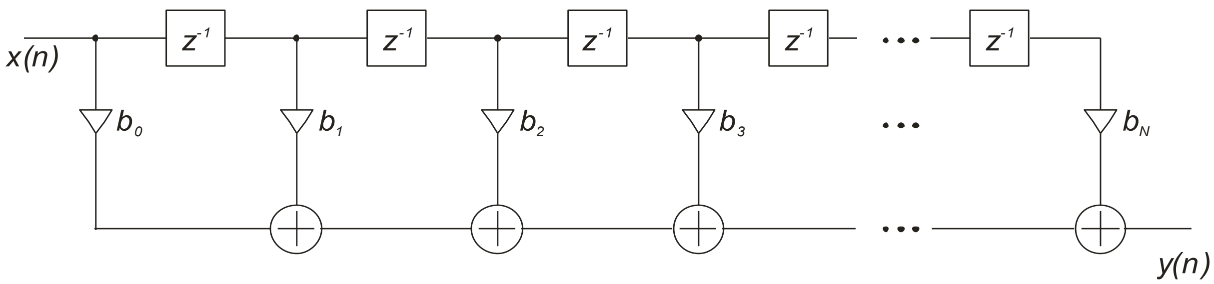

Fig. 8. Scheme of a FIR filter

In the FIR filter the output signal is calculated with the use of N subsequent samples of the signal where N is the order of the filter. The parameters $b_1 - b_N$ are the coefficients of the filter which may be adjusted in the way to outfilter or pass a needed frequency band from the signal. A FIR filter can be developed by means of the FFT (Fast Fourier Transform) transform blocks in the way shown in Fig. 9.

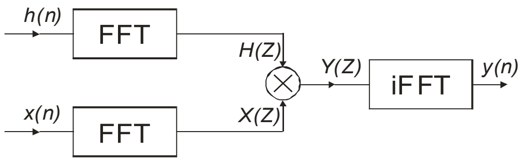

Fig. 9. FFT-based on FIR filter

Thanks to the application of FFT algorithms the efficiency of calculation of the discrete convolution is better which makes the filter operation faster.

Another type of filter which can be implemented for this task is a IIR (Infinite Impulse Response) filter which in contrary to the FIR filter includes a feedback loop. This type of filter facilitates faster operation but also is less stable which may lead to generating oscillations.

The last method which has been taken into account was the LMS (Least Mean Square) filter based on adaptive signal processing. A basic scheme for this algorithm is shown in Fig. 10.

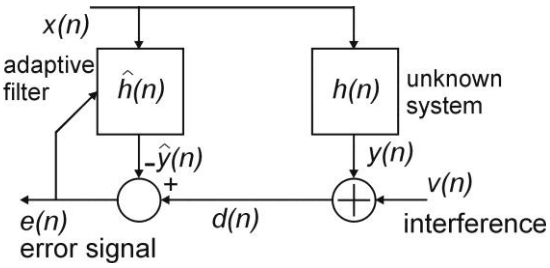

Fig. 10. Basic scheme for the LMS adaptive filter

An LMS algorithm was prepared at the IPPLM but could not have been tested due to lack of speckle interferometry data which was not provided by other labs and also due to lack of funds for software (originally project was submitted as PS with additional funds for software purchase, although only BS has been finally provided by EFDA).

Conclusions

The works conducted at the IPPLM in 2011 brought good results especially in terms of the development of the removal method with the use of fiber laser. The dustless and substrate friendly removal has been demonstrate; however; it is still needed to investigate the behaviour of the cleaned areas by means of material research and test its susceptibility against fuel re-absorption in plasma operation conditions. In spite of long delays in sample preparation in collaborating labs, the task on assessment LIBS for estimation of fuel inventory in next-step fusion reactors gave good preliminary results yet in 2011. It was shown that LIBS indications significantly differ for the DLC samples which included different deuterium amounts. Nevertheless for more precise results more experiments as well as application of material research methods on the calibrated samples in collaborating labs is needed.

The results of film break-up processes brought new interesting results among which the important messages was the long timescale of dust generation in case of the co-deposit release by means of high power pulses from Nd:YAG and no record of dust generation in case of the removal with the fiber laser.

In the field of development of algorithms for signal processing for speckle interferometry in vibration conditions, a few interesting algorithms have been studied and parts of the code for LMS have been developed.

3.3 Inertial fusion energy "keep-in-touch" activity

Analysis of emerging options of IFE on the basis of results of experiments and numerical modeling

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Abstract

In experiment at PALS (Prague Asterix Laser System) the previous researches were continued, which were aimed at improvement of parameters of plasma stream (jet) produced by cumulative acceleration of a thin, conically shaped, foil. The cumulative effect was induced by laser produced-ablative plasma expansion from the outer cone surface. This method of plasma jet creation is so called the RAS method (Reversed Acceleration Scheme) [1, 2]. The new target construction, in which the conically shaped foil was connected with the pressure cavity, was tested. Despite the fact that the results obtained in this experiment are not satisfactory, it seems that this kind of target has a certain potential for realizing ICF by Fast Ignition Concept [3-5].

Introduction

Our previous investigations concerned the direct and indirect methods of plasma jet generation using for this reason the conically shaped foils [6]. The direct method is that the cone is irradiated directly by a laser beam. In the latter case the foil cone is irradiated by an ablative plasma produced from the massive target placed behind the cone. In both the cases, however, it is crucial to match the foil thickness to the laser energy so that melting and evaporation of the foil appears before its acceleration. It allows to avoid acceleration of the solid cone. This condition is very difficult to be fulfilled. Therefore, to get the plasma jet with a good quality it is necessary to examine several cones with different thicknesses at the same laser energy. Unfortunately, because of technical problems we can only use the thinnest foil with a 10 μm thickness. So, the results obtained by both the methods used are rather moderate. Even if the laser energy is enough for cone evaporation, its acceleration is not effective. This is why we have proposed a new method of plasma jet forming with the use of the foil cone, however modified by its connection with the pressure cavity. The ablative plasma pressure is here employed as an additional accelerator.

Experimental results

The target construction being combination of the Al foil cone and the pressure cavity is shown in Fig 1. To recognize this target potential, in this preliminary experiment dimensions of the pressure cavity were taken without deeper analysis. Investigations were carried out at the PALS (Prague Asterix Laser System) iodine laser system. The laser beam passes trough a small hole in the pressure cavity and heats the cone. To irradiate the target the first harmonic of laser radiation (λ =1315 nm) with energy about 500 J in a pulse of 250 ps width was used. The main diagnostic tool used in the experiment was a 3-frame interferometric system, allowing to obtain a sequence of interferograms with a time interval of 3 ns between them. Additionally, 4-frame x-ray frame camera with an exposure time below 2 ns was used.

The preliminary results are shown in Fig. 2. These results are not satisfactory. Although we can observe the plasma stream generation, however its parameters (especially its velocity) are not yet acceptable. It seems that a failure reason is the incorrect target dimensions. First of all, the foil thickness should be smaller. May be, the pressure cavity volume is also too great and a distance between the hole and the cone, which is crucial for the target irradiation, is not proper too. So, to do such target with great accuracy, optimization simulations and advanced technology are necessary.

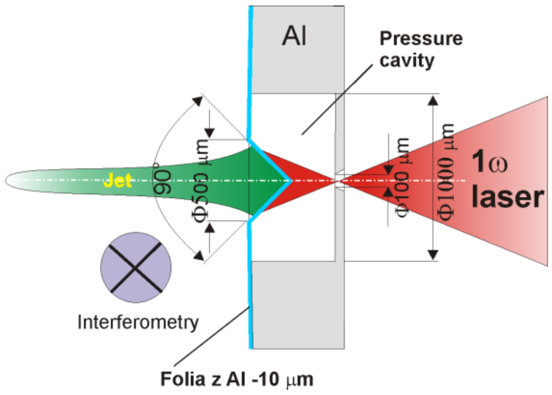

Fig. 1. Target construction constituting combination of classic and pressure methods

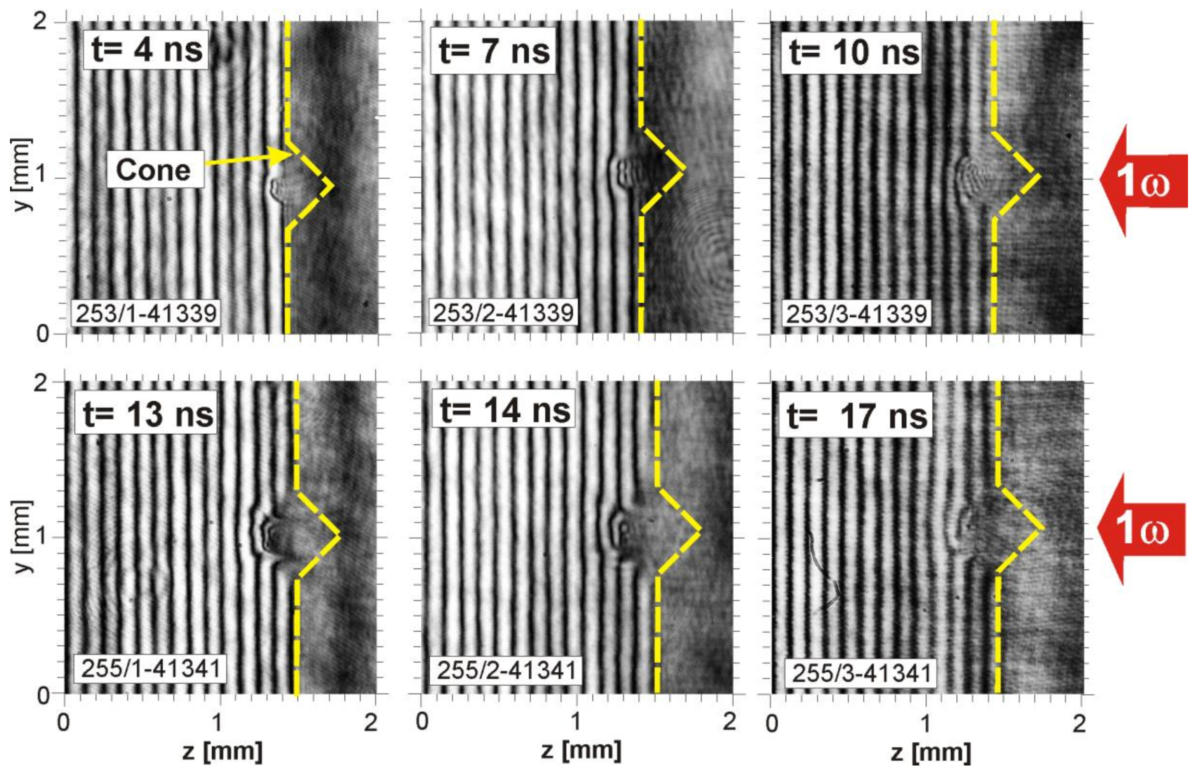

Fig. 2. Sequence of interferograms illustrative the plasma stream generation from the targets with combined construction

Conclusions

This preliminary experiment has shown that to obtain the good quality plasma stream by means of the described above method, optimization researches (numerical simulations) are necessary to determine parameters of proposed construction of the targets, e.g. thickness of foil, cone dimensions and angle, dimensions of pressure cavity with respect to laser energy and the like. Such numerical simulations, done with 2D magneto-hydrodynamical codes, are planned to be undertaken by theoretical teams from Lebedev Physical Institute in Moscow and Bordeaux University (Centre Lasers Intenses et Applications-CELIA).

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