20PA-014

Formation of aerosol in an inertial fusion reactor II
-Visual analysis by volume rendering-
レーザー核融合炉内でのエアロゾル形成II
～ボリュームレンダリングによるビジュアル解析～

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We propose visualization of colliding plasma plumes generated from nuclear reactor walls by laser ablation. We pile up a time series of 2D photo images taken during the experiment and create 3D volume data in the XYT (space-time) space. We visualize the created 3D data with volume rendering, which enable us to observe the whole-time behavior within one static image. Our visualization also enables direct comparison of two experiments by visualizing their local correlation based on the particle-based volume fusion. We make demonstration of visually comparing experiments of the orthogonal and frontal collisions of the plasma plumes.

1. Introduction

Nuclear fusion generation is the power generation technology, which is expected to be established in near future [1,2]. During the fusion reaction, many high-energy particles (X-ray photons, α-particles, carbon particles, etc.) are created and collide with a reactor wall. This paper reports our visualization to help physically to analyze behavior of plasma plumes. Our visualization is based on the particle-based rendering that we recently proposed [3].

2. Data and Method

2.1 *Visualization data*

We have been executing experiments to observe behavior of a single plasma plume and double colliding (crossing-over) plasma plumes [1,2]. The plasma plume(s) are measured every 50 nanoseconds and recorded with an ICCD camera as 2D images. In this paper, the experiments are conducted with two types of target placement, frontal and orthogonal setups, which leads to the frontal and orthogonal plasma plume collisions, respectively. The visualization uses the time series data of top-view and side-view photo images.

2.2 *Volume data in XYT space*

We create the 3D volume data by simply piling up the time series of 2D photo images in chronological order. This aims at applying volume rendering techniques to analyze the data. The created 3D data become 3D regular-grid volume data with 2D special (XY) information and 1D time-dimensional (T) information (see Fig.1). By visualizing these 3D volume data in the XYT space, we can observer the full-time behavior of the plasma plumes with a single static 3D image at one glance. Such observation is difficult by using the conventional time-dependent visualization based on the animation.

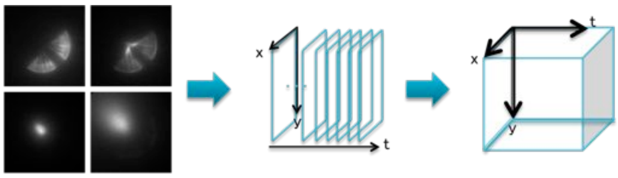


Fig.1 How to create 3D volume data in the XYT space

2.3 *Rendering method*

To execute the visualization described in Section 1, we use the particle-based volume rendering [3], which is a kind of transparent point-based rendering. Its prescription is very simple. First, volume data are resampled and converted to multiple point clouds, each of which forms an independent point distribution proportional to the voxel data distribution. Second, each point cloud is independently visualized to make an intermediate image. Third, the intermediate images are averaged to create a final transparent image. This rendering method is suitable for fused visualization of multiple datasets. The fusion is realized by simply merging point clouds of the constituent datasets. In this paper, we fuse the XYT-space volume datasets that record frontal and orthogonal collisions of plasma plumes, respectively.

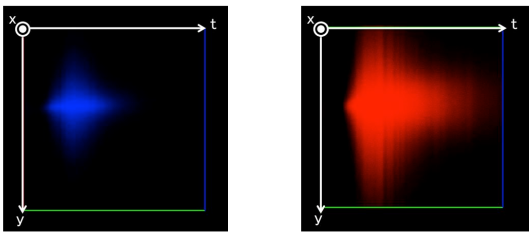
Additionally, we propose application of the fused visualization to visual analysis of the "local correlation" between different volume datasets. Here, the local correlation is defined by the similarity of the local density. The particles are counted in each cubic cell created by dividing the whole XYT space in a rectangular pattern. To visualize the distribution of the local correlation, we assign red color to the frontal collision and blue color to the orthogonal collision. Then, the colors are gradually made approach white according to the strength of the local correlation. This means strength of the local correlation is visualized by "whiteness" in the fused visualization. The color reflecting the local correlation in the *i*-th cubic cell is decided as follows:

$$\vec{C}^{(i)} = \left(n_a^{(i)}\vec{R} + n_b^{(i)}\vec{B} + \min\left(n_a^{(i)}, n_b^{(i)}\right)\vec{G}\right) / \max\left(n_a^{(i)}, n_b^{(i)}\right)$$

Here, $n_a^{(i)}$ and $n_b^{(i)}$ are the numbers of red and blue particles in the *i*-th cubic cell, respectively. $\vec{R} = (1,0,0), \vec{G} = (0,1,0), \vec{B} = (0,0,1)$ are base vectors in the RGB color space.

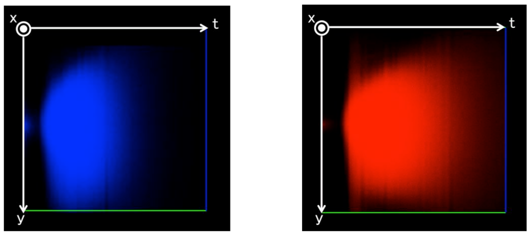
3. Visualization Result

Our visualization results are shown in Figs.2-4. Fig.2 shows non-fused volume rendering of the data created by piling up top view photo images in the XYT space. Fig.2 (a) shows the result of the orthogonal collision and Fig.2 (b) of the frontal collision. Fig.3 shows non-fused volume rendering of the data created by piling up side view photo images in the XYT space. Fig.3 (a) shows the result of the orthogonal collision and Fig.3 (b) of the frontal collision. Fig.4 shows the fused visualization of the two types of the collisions. Fig.4 (a) shows the result for the top view images and Fig.4 (b) for the side view images. In Figs.2 and 3, we can see that the plasma plumes spread more widely for the frontal collision both in space and time. In Fig.4, we can see that the orthogonally colliding plasma plume becomes visible, i.e, hot enough, a little earlier, while the frontally colliding plasma plume survives much longer.



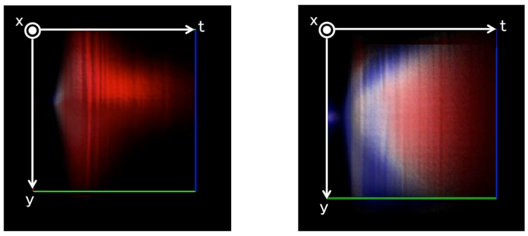
(a) the orthogonal collision (b) the frontal collision

Fig.2 XYZ-space volume rendering of the plasma plume collisions (top-view time-series images)



(a) the orthogonal collision (b) the frontal collision

Fig.3 XYZ-space volume rendering of the plasma plume collisions (side-view time-series images)



(a) the top view images (b) the side view images

Fig.4 XYZ-space fused visualization

4. Conclusions

In this paper, we proposed visualization of colliding plasma plumes that are generated from nuclear reactor walls by laser ablation. Our visualization uses the particle-based 3D volume rendering [3]. We create volume data in the XYT space, which is a space-time 3D space, by piling up a time series of 2D photo images taken during the experiment. We visualize the created 3D data using the volume rendering, which enables us to visually analyze the whole-time behavior within one static image at a glance. Our visualization also enables direct comparison of multiple different experiments by visualizing their local correlation.

References

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