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Wide-field, High-resolution Snapshot Compressive Microscopy for Laser Materials Manufacturing

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Abstract: We propose a dual-path snapshot temporal compressive microscopy for laser materials manufacturing. Specifically, using such method with camera working at 50fps, we can reconstruct video with 2mm FOV and 775nm resolution at 500fps. We expect this method will find applications in laser materials manufacturing.

1. Introduction

Microscopy has revolutionized our ability to observe and understand the world, enabling groundbreaking discoveries in fields such as medicine, biology, and materials science. However, traditional microscopy techniques have limited functionality when it comes to capturing high-resolution images of large areas quickly. There are several ways to increase field of view (FOV) and resolution simultaneously. Direct ways involve using objective lens with high numerical aperture or increasing sensor size. Both methods require expensive hardware, leading to increased costs. Another approach is through the use of computational techniques such as Fourier Ptychography. This method involves acquiring a series of low-resolution images, each with slightly different illumination angles, and computationally merging them to produce a high-resolution image. However, acquiring a large number of images with different illumination angles can be time-consuming, which may be a limitation for some applications where high-speed imaging is required.

A promising approach for addressing the limitated imaging speed is snapshot compressive imaging[1], which combines hardware and software to enable high-speed in a single snapshot. However, like many imaging methods, one can not satisfy high resolution and large FOV simutaneously. To further improve the trade-off between spatial resolution and FOV in snapshot compressive imaging, we propose a dual-path snapshot compressive microscopy (DP-SCM). DP-SCM consists of two parallel optical paths, one optimized for high-resolution imaging and the other for wide-field imaging. By combining these dual measurements, DP-SCM can reconstruct high-resolution images over a large FOV at high imaging speed.

2. Method

In temporal snapshot compressive imaging, see Fig. 1, a high-speed camera captures a sequence of frames at a much higher frame rate than the final desired frame rate. A patterned mask, such as a binary pseudorandom sequence, is placed in front of the camera lens, which modulates the incoming light and allows for the capture of a compressed version of the scene. After the acquisition of these compressed measurements, a deep neural network, is used to reconstruct the video from the dynamic scenes.

On the basis of temporal snapshot compressive imaging, we propose dual-path snapshot compressive microscopy, see Fig. 2(a). The DP-SCM system consists of two parallel optical paths, each optimized for a different range of resolution and FOV.

In the wide-field path, samples are imaged into DMD through a 4F system (OL and L3). The resulting dynamic scenes (moving sample) is modulated by the DMD and is further relayed to the CCD through L4. The overall magnification in the path is 2.6X, providing a large FOV of 2mm as shown in Fig.2(b). The high-resolution path employs the same objective lens but uses a long-focal-length lens (L1). Following the modulating path, this results in high resolution, with the smallest line having a linewidth of 775nm being clearly visible, see Fig.2(c). Note that the scene is illuminated by a white-light LED.

We validated snapshot compressive imaging in high-resolution path by moving the sample in a translation stage and captured the coompressed measurement, see Fig.2(d). After the measurement was acquired, it is processed to reconstruct video by using an efficient neural network. Building upon the remarkable achievements of convolution and Transformer[3] in computer vision, we have designed a reconstruction network that leverages the strengths of

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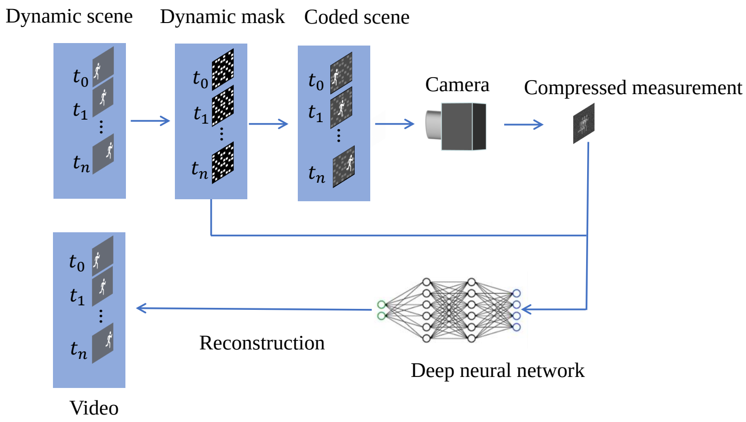

Fig. 1. Principle of temporal snapshot compressive imaging.

both techniques. This novel approach combines convolution and Transformer to effectively model both local and non-local pixel dependencies. In this way, using camera working at 50fps, setting compressed ratio (CR) to 10, dynamic imaging with high resolution and large FOV at 500fps is realized without losing reconstruction quality, see Fig.2(e).

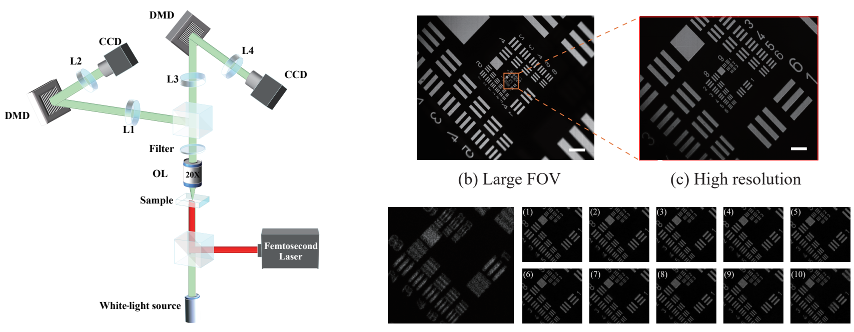

Fig. 2. Wide-field, high-resolution snapshot compressive microscopy. Scale bars in (b) and (c) are 250um and 25um respectively.

3. Conclusions

Our DP-SCM approach offers a promising solution for achieving high speed, high-resolution and wide-field imaging simultaneously without sacrificing image quality, opening up new possibilities for applications in medical diagnosis, biological imaging, and materials science. We expect this method will find more applications in fields of laser materials manufacturing.

References

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