© 2009 OSA/CLEO/IQEC 2009

Single Detector Single Shot High Resolution Imaging

Qi Song[1], Feng Qian[1], en-Kuang Tien[1], Metin Akdas[1], Joerg. Meyer[1,2] and Ozdal Boyraz[1]
[1]*EECS Department, UC Irvine, CA, 92697,*
[2]*Biomedical Engineering Department, UC Irvine, CA, 92697*
Email: oboyraz@uci.edu

Abstract: We propose and demonstrate single detector real-time line imaging with up to 1µm resolution at 1 line/50ns capture rate. Experimentally we demonstrate real time line imaging of <25µm particles and patterns such as fingerprints.
©2009 Optical Society of America

OCIS codes: (110.2970) Image detection systems; (300.6500) Spectroscopy, time-resolved

1. Introduction

Real-time optical imaging is an attractive approach for biological sample imaging and capturing dynamic properties of target objects. Different Fluorescence or scattering based mechanism has dominated in optical detection and imaging field, so far [1]. WDM based space-wavelength mapping has been proposed as a powerful technique for optical imaging and detection in confocal microscopy where different wavelength is effectively separated and cross-talk between different wavelength channels is reduced to increase the resolution of the system [2]. In a separate field of study, time-wavelength mapping has provided unique solution for real-time optical sampling and analog-to-digital conversion [3-5]. Here, time domain profile of an RF signal can be mapped to wavelength domain; thus, the spectral shape can be retrieved directly in the time domain by using a real-time oscilloscope after dispersive time stretching process [4].

In this paper, WDM (wavelength division multiplexing) based time-space-wavelength mapping is proposed and illustrated for single detector high resolution real-time optical detection and imaging. Experimentally we demonstrate real time line imaging of <25µm particles and patterns such as fingerprint stains. Experimental results indicate that optical imaging with resolution as low as 1µm and capture rate of 1 line/50ns can be achieved by the proposed single detector single shot scanning system.

2. Experimental setup

Figure 1 illustrates the experimental setup used for demonstration of single detector single shot high resolution imaging. A broadband optical pulse is generated in a nonlinear normal dispersion fiber by launching femtosecond pulses generated by a fiber laser. The generated light is then dispersed by a grating based dispersion compensation module (1300ps/nm) and hence time wavelength mapping is produced by linear dispersion. The temporally dispersed supercontinuum is then dispersed in space by using a 600 lines/mm diffraction grating and then focused on the target object at the front focal plane of the objective lens. Light transmitting through the target object is coupled back using a symmetrical beam path and collected by an InGaAs detector. Finally, an 8GHz real-time digital oscilloscope is used to collect digitized image data for real-time processing.

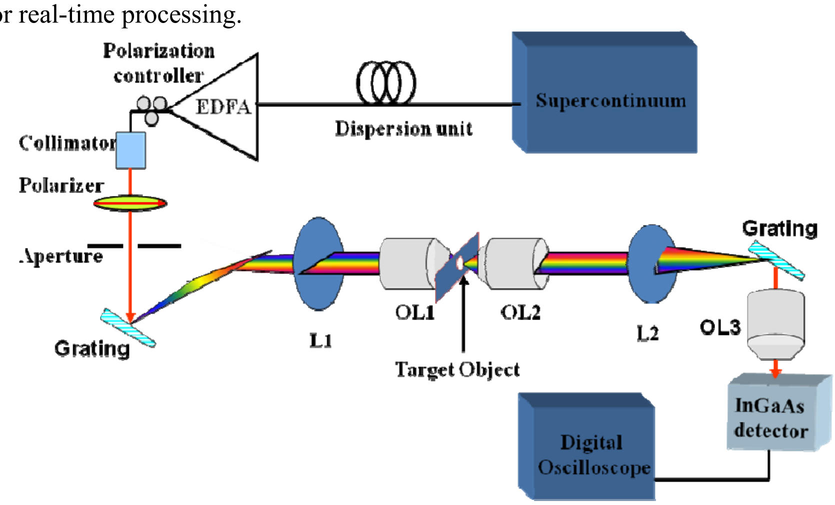

Figure 1 Schematic diagram of the WDM based time-space-wavelength imaging system.L1, L2, cylindrical lens (FL 15cm); OL1, 20X objective lens; OL2, 40X objective lens; OL3, 20X objective lens.

978-1-55752-869-8/09/$25.00 ©2009 IEEE

© 2009 OSA/CLEO/IQEC 2009

3. Experimental Results and Discussion

Performance of the system is evaluated by scanning different-sized objects in the vertical direction. Since spectral mapping in lateral direction can serve as one line of the image, scanning in only vertical direction will provide enough information of target object. Experimentally, micron-sized glass particles (~25um) and fingerprint stain on a glass surface (each line is ~200μm) are utilized as target objects. When the laterally dispersed incoming light encounters with the target object, random amplitude modulation is created on the transmitted signal. By comparing the modulated signal with stored background signal we can extract the information regarding the position of the object and density of the scatterers. By retrieving the single shot data from the time domain using a single detector and an oscilloscope, imaging and detection of the target object can be realized in real-time. For instance, Figure 2(a) illustrates a retrieved image of a random glass particle which has a size of approximately 25um. Here, the line capture rate is determined by the laser pulse rate fixed at 1line/50ns.

The system is also capable of scanning larger object effectively by replacing objectives lens with cylindrical lenses in fig 1. Figure2 (b) illustrates the single shot imaging of a fingerprint stain on a glass surface. Here, the fingerprint stain in 2mm×1cm area is scanned to illustrate the proof of concept.

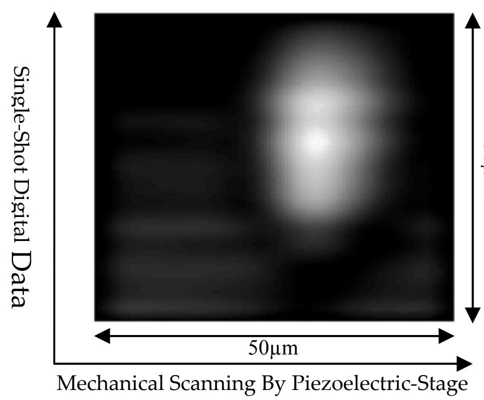

Figure 2(a) Retrieved scanning image of a micron-sized particle of 25um

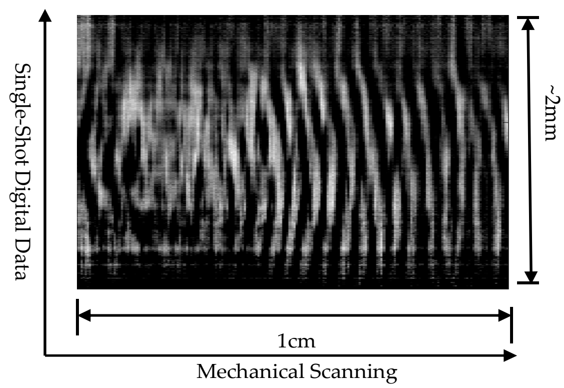

Figure 2(b) Retrieved scanning image of a fingerprint stain in a 1cm×2mm surface. Each line of the fingerprint is approximately 200μm wide.

It is estimated that the resolution of this scanning system is inversely proportional to the optical bandwidth ($\Delta\lambda$), fiber dispersion (D_{fiber}) and RF bandwidth (BW_{RF}) of the detector and proportional to the beam width at object plane ($\Delta\lambda_x$) as: $Resolution \propto \dfrac{\Delta\lambda_x}{\Delta\lambda \times D_{fiber} \times BW_{RF}}$. Hence, by selecting the appropriate bandwidth and dispersion parameters, resolution down to 1μm is achievable. The imaging system proposed clearly demonstrates that it can resolve sizes of objects with different order of magnitudes. As expected, increasing the scan area is feasible without losing the resolution by using larger bandwidth optical sources. Also, target objects of various profiles can be readily distinguished by this configuration. The application of this proposed scheme may include detection of objects of arbitrary shapes and evolution of dynamic process, which can potentially be recorded by single detector imaging system.

4. Summary

We demonstrate the feasibility of single shot single detector high resolution imaging by time space-wavelength mapping technique. We experimentally demonstrate single shot imaging of <25μm objects at 1 line/50ns capture rate. Potentially, 1μm resolution is achievable.

5. References

[1] J. Enderlein, T. Ruckstuhl, and S. Seeger, "Highly Efficient Optical Detection of Surface-Generated Fluorescence," Appl. Opt. **38**, 724-732 (1999)

[2] K. Shi, S. H. Nam, P. Li, S. Yin, and Z. Liu, "Wavelength division multiplexed confocal microscopy using supercontinuum," Optics Communications 263(2), 156-162 (2006).

[3]D. R. Solli, ChouJ, and JalaliB, "Amplified wavelength-time transformation for real-time spectroscopy," Nat Photon **2**(1), 48-51 (2008).

[4]Y. Han and B. Jalali, "Photonic Time-Stretched Analog-to-Digital Converter: Fundamental Concepts and Practical Considerations," J. Lightwave Technol. 21, 3085- (2003)

[5] C. Jason, B. Ozdal, S. Daniel, and J. Bahram, "Femtosecond real-time single-shot digitizer," Applied Physics Letter 91(16), (2007).