Fast Dispersive Laser Scanner by Using Digital Micro Mirror Arrays

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Abstract: We demonstrate fast dispersive laser scanning system by using MEMS digital micro-mirror arrays. Experimentally, we scanned ~20mm^2 in 200μs with ~175μm lateral and ~216μm vertical resolution that can be controlled by using 1024x768 mirror arrays.

OCIS codes: 070.6120 Spatial light modulators, 120.5800 Scanners, 230.3990 Micro-optical devices

1. Introduction

High throughput fast laser imaging systems requires scanning a large area in a short period of time and they are desired for applications pertinent to many areas such as defense, microscopy, surface metrology and manufacturing technology [1-3]. Up to date, various types of laser scanning technologies such as the galvanometric mirrors and acousto-optic deflectors (AODs) which provide 2D scan rates of respectively 100 Hz and ~1 kHz have been proposed [3-4]. MEMS based digital micro-mirror devices (DMD) provide extremely faster switching speeds (<30μs), >90% fill factor, higher than 88% diffraction efficiency, cover wide bandwidth (UV to NIR), provide exceptional stability and excellent controllability over thousands of individual micro mirrors that can be used for fast beam steering applications [5]. In this paper, we propose and demonstrate a novel method for 2D spatial disperser by using these MEMS based digital micro-mirror arrays in an amplified time stretched dispersive system. In this preliminary experimental work we demonstrate scanning ~20mm^2 in 200μs with ~175μm lateral and ~216μm vertical resolution that can be controlled by using 1024x768 mirror arrays. We also show that by using the state of the art MEMS technology 2D raster scan rates up to 32.5 kHz is achievable.

2. Experimental Setup and Results

Fast wide area dispersive laser scanner is mainly designed by combining the broadband illumination, wavelength-to-time mapping and 2D space-wavelength mapping modules, Fig. 1a. The supercontinuum (SC) pulses centered at 1590nm are used as 20nm wide broadband source to capture the spectral modulation that is transformed into RF signals after time wavelength mapping. In the first stage, the broadband SC pulses are propagated through the dispersion compensation module (DCM) with −675 ps/nm dispersion to map the spectral information into temporal waveform. In order to compensate the system losses and to obtain a better signal to noise ratio, a flat gain Raman amplifier is designed to provide a uniform amplification through the DCM. The Raman amplification with ~10dB net gain and <0.5dB gain ripple is introduced by using diode lasers with different wavelengths in a hybrid pumping configuration.

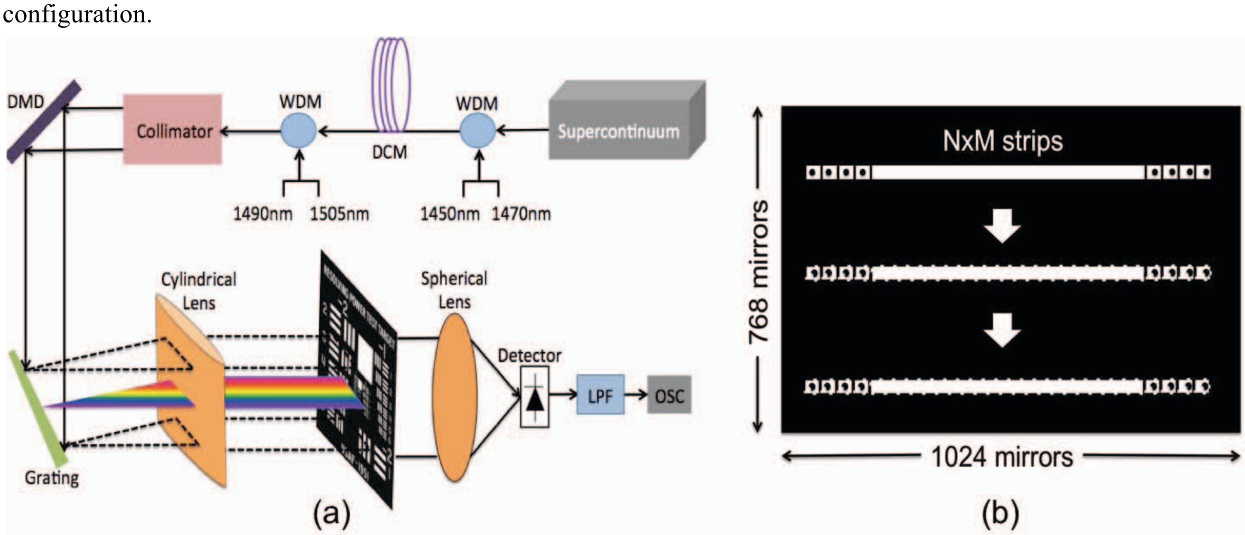

Fig. 1. The experimental setup for fast all-optical wide area laser scanning system (a). The vertical scanning by sliding horizontal strip lines (b).

Then, the optical beam is expanded to illuminate the active area of the digital micro mirror device (DMD), which consists of 1024x768 micro mirrors with 10.8μm pitch size. By individually controlling the states of the micro mirrors either to ON or OFF ($\pm 12^0$ tilt angle) states, the beam is digitally divided into segments and mapped to specific locations over the image plane, namely beam steering. The spectral content of the time stretched SC pulses at different points is spatially dispersed by the diffractive optics which is composed of a blazed diffraction grating with 600 lines/mm grove density and a Fourier lens with 200mm focal length to collimate the dispersed wavelengths and to focus the beam for better resolution. After being mapped over the focal plane, the spectrum of the pulses is shaped by the target image. The temporally and spectrally modulated signals are captured by an optical detector (1.2GHz) connected to a real time oscilloscope (8GHz).

The beam expanded over the DMD is sliced and reflected into the imaging system by using horizontal strip type patterns, Fig. 1b. In order to scan the whole image, DMD and the diffractive optic are utilized as a 2D spatial disperser. Overall, the lateral scanning is achieved via spatially dispersing time stretched broadband pulses over the image plane, namely space-to-wavelength mapping. By reducing the diffraction limit, namely increasing the ratio of the beam size to lens focal length ($d/f > 0.1$), high lateral resolution down to <10μm is attainable. Vertical scanning, on the other hand, is achieved by vertically shifting the NxM excitation mirror arrays on the DMD via using dynamic binary patterns. High vertical scan rates up to 32.5 kHz with resolution down to single mirror pitch size (10.8μm) can be achieved. In this preliminary experimental study, we have used optical beam with ~5mm beam size and 20x600 horizontal lines to vertically scan the target image which consists of vertical black and white strips with different spatial frequencies. The proposed system can scan ~20mm^2 wide area with ~175μm lateral and ~216μm vertical resolution within 200μs (5kHz sacnning rate). The resolution performance of the system is mainly limited by the detection system. Electro-optic detector with 1.2GHz RF bandwidth limits the achievable temporal resolution to ~800ps which corresponds to ~1.2nm spectral (due to -675ps/nm DCM) and ~145μm spatial resolutions.

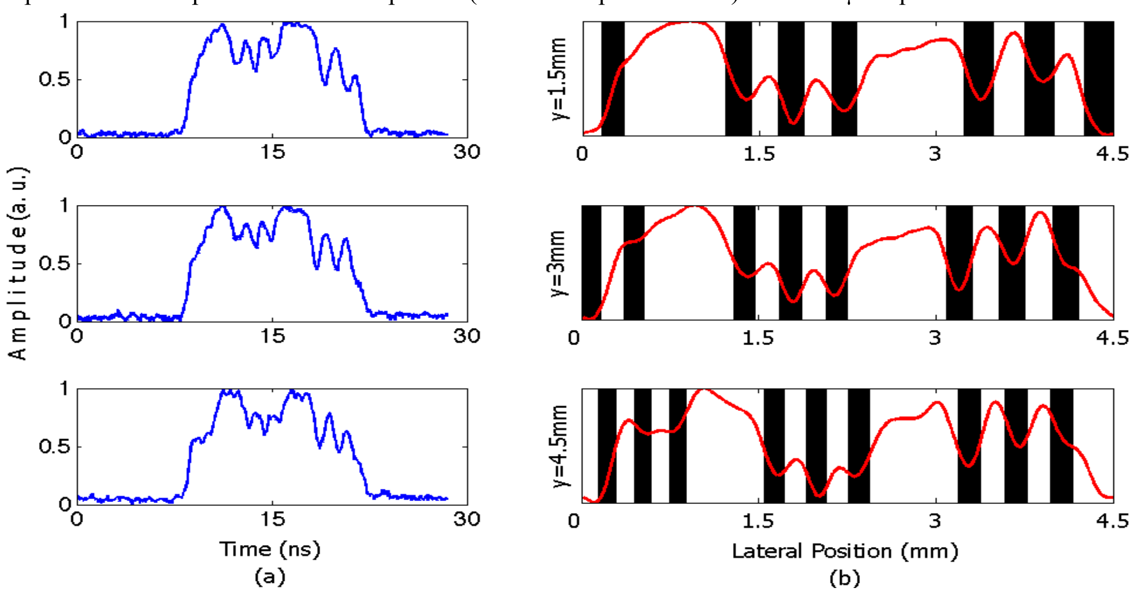

Fig. 2. The lateral images at different vertical scanning positions captured by the single SC pulses at 20MHz rate (a). The extracted modulation patterns (red lines) for the images (~216μm thickness) at different vertical positions illustrate the resolution performance of the system (b).

3. Conclusion

We have proposed a fast dispersive laser scanning system by using MEMS micro mirror technology. Two-dimensional beam steering is employed by combining the space wavelength mapping for the lateral scanning and digital micro mirror arrays for vertical scanning. We estimate that MEMS based amplified time stretched system exhibits fast vertical scanning up to 32.5 kHz with resolution down to single mirror pitch size of 10.8μm.

4. Acknowledgement

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5. References

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