Integrated probe for laser Doppler velocity distribution measurement

Prof. Koichi Maru, Faculty of Engineering and Design
e-mail: maru.koichi@kagawa-u.ac.jp

1. Introduction

Noninvasive techniques for measuring velocity distributions have been indispensable for research and industrial applications. In some applications to fluid flow measurements, velocity distribution measurements in a two-dimensional (2-D) cross section of the flow are often required. Among various techniques for velocity distribution measurements, scanning differential laser Doppler velocimeters (LDVs) are suitable for accurate distribution measurements of the transverse velocity component on a cross section. As compared to conventional LDVs based on bulk optics, integrated waveguide optics can provide advantages of realizing a miniaturized probe with an extremely compact size. In this study, we propose an integrated probe using a combination of nonmechanical scanning and spatial encoding for 2-D cross-sectional velocity distribution measurements.

2. Integrated probe

The structure of the proposed probe is illustrated in Fig. 1. A light from the tunable laser is input to the integrated probe and split into $2N$ beams to generate N measurement points. The frequencies of the beams are shifted with optical serrodyne modulation by the phase shifter array. The modulated beams are fed to the transmitting focusing grating couplers and output from the probe. Two beams from the grating couplers oppositely arranged are intersected to generate spatially encoded measurement points. By virtue of the dispersion function of the grating couplers, the measurement points are scanned in the depth direction by changing the wavelength and accordingly changing the diffraction angles of the beams from the grating couplers. Velocity information at different measurement points is extracted by letting the carrier frequencies of Doppler-shifted signals for all of the measurement points be different from each other.

To realize a planar integrated probe without additional lenses, the output beam from the transmitting grating coupler should be directly focused around the measurement point. In this study, we investigated chirped grating couplers in which the grating period and fill factor are chirped. The simulation results of the beams from two oppositely arranged grating couplers are shown in Fig. 2. The output beams were successfully scanned over 3.5-mm scanning range according to the wavelength change. The proposed LDV would be attractive in applications such as industrial fields or microfluidics for measuring the cross-sectional velocity distribution of fluid flow in a small area.

This work in part was supported by JSPS KAKENHI Grant No. 15H04018 and 19K04426.

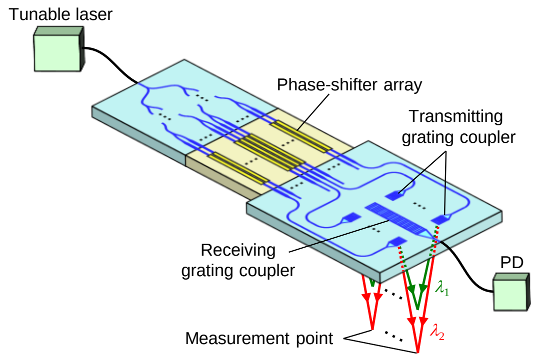

Fig. 1. Concept of the integrated probe.

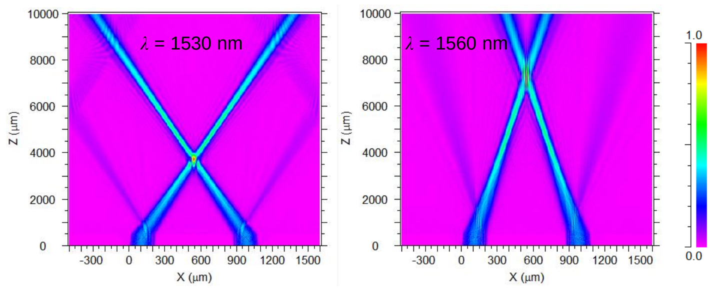

Fig. 2. Simulation results of the output beams.