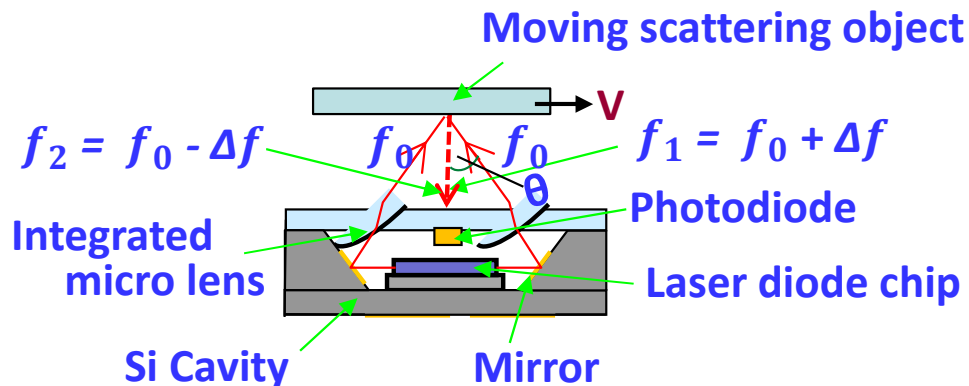
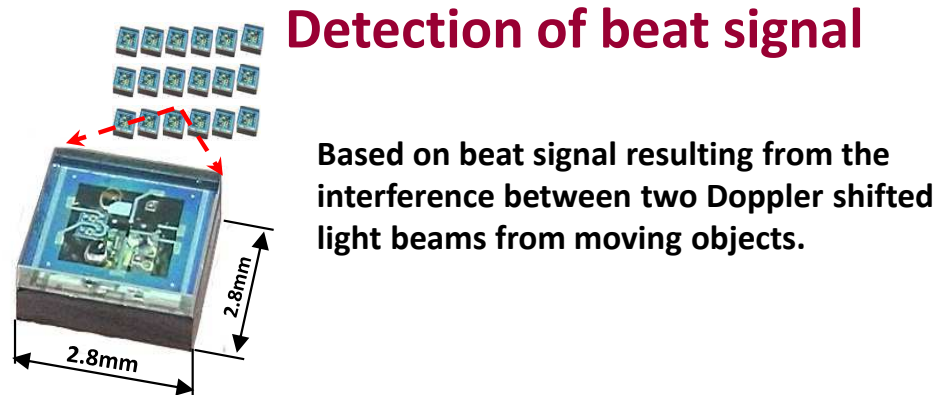


# Two types of MEMS Doppler sensors

## Micro Laser Doppler Velocimeter



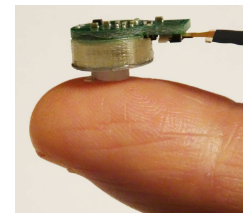
$\Delta f$ : Doppler shift

$$\text{Velocity } V = \text{Wavelength } \lambda \times \text{Beat frequency} / 2\sin(\theta)$$

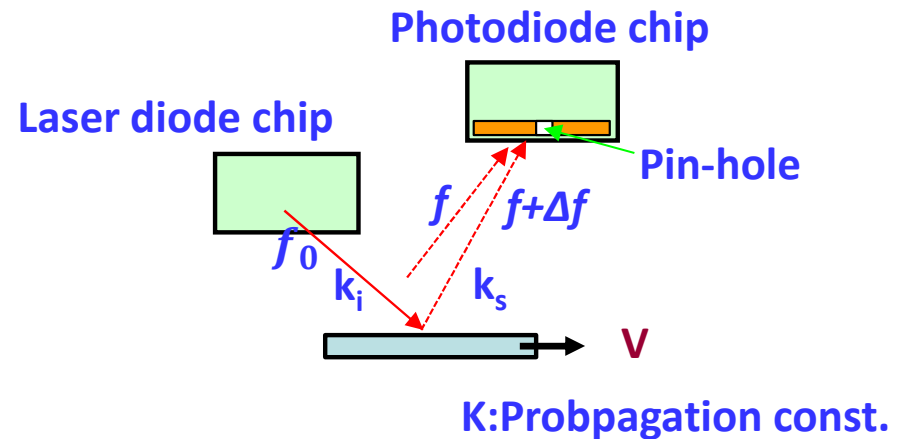
Can measure the absolute value of the velocity

## Micro blood flowmeter with a built-in contact pressure sensor

### Probability application to the behavior of the speckle pattern



Based on the probability application to the behavior of the speckle pattern resulting from interference of scattering light.



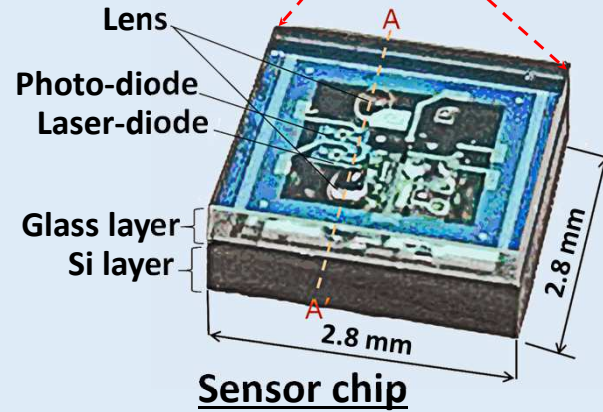
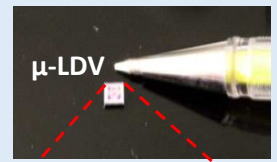
$$\int f \cdot P(\omega) d\omega \propto \text{Velocity } V, \text{ Blood flow } Q$$

$\omega: 2\pi f$

Immune to the vibration and the fixing direction of the sensor

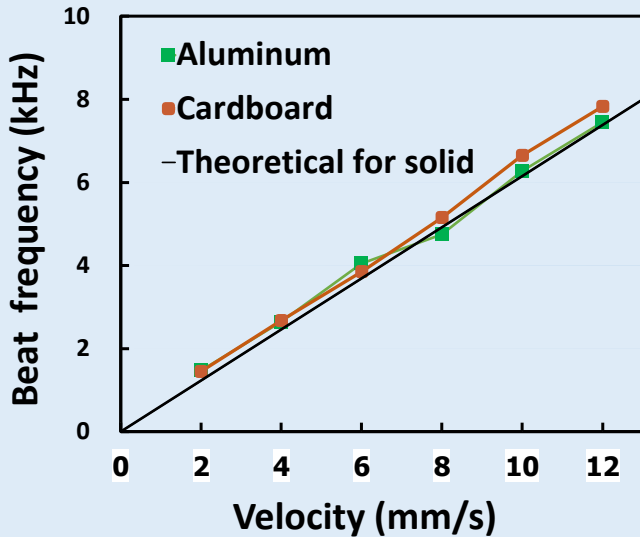
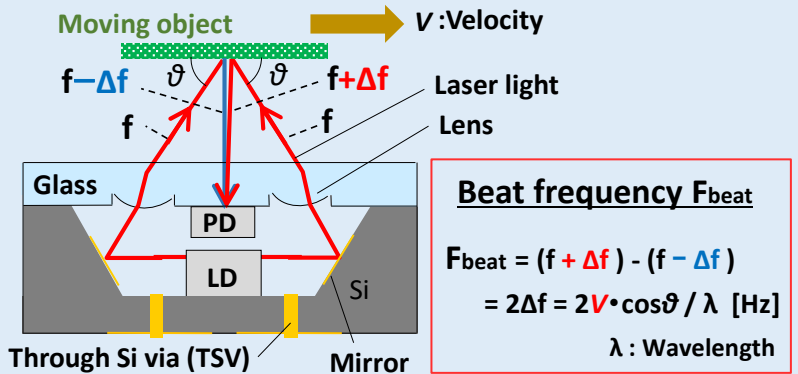
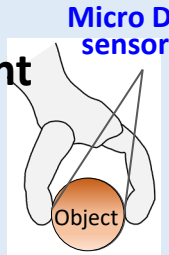
# Micro Laser Doppler Velocimeter ( $\mu$ -LDV)

- Extremely small size: 2.8mm x 2.8mm x 1mm thick
- Non-contact velocity (speed) parallel to the sensor surface is measured
- Measurement speed range : 10-20,000 $\mu$ m/s
- Measurable materials : Plastic, metal, paper, liquid, etc., except for mirrors and colorless transparent objects

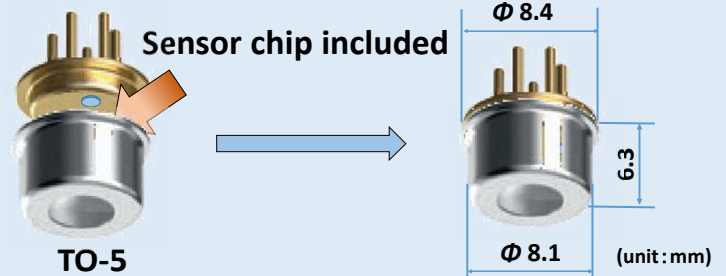


## Applications

Speed measurement in tight spaces, e.g. Robotic hand slippage detection

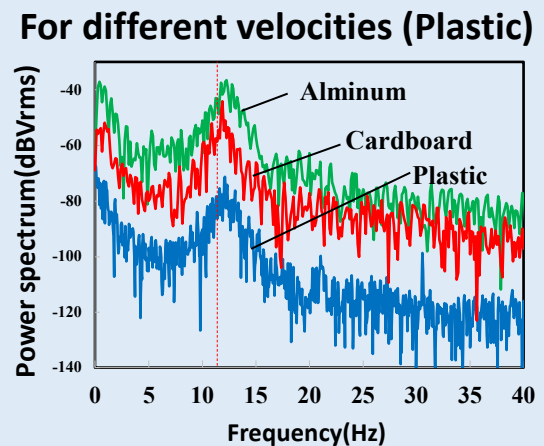
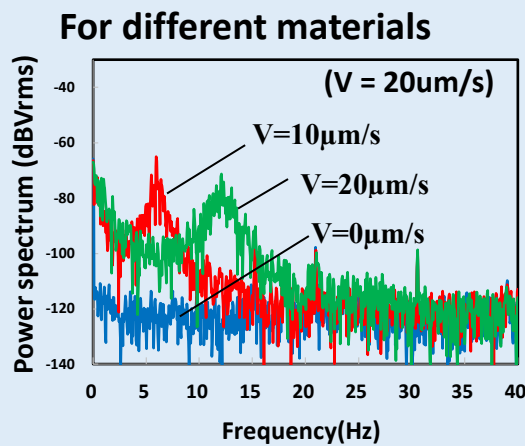
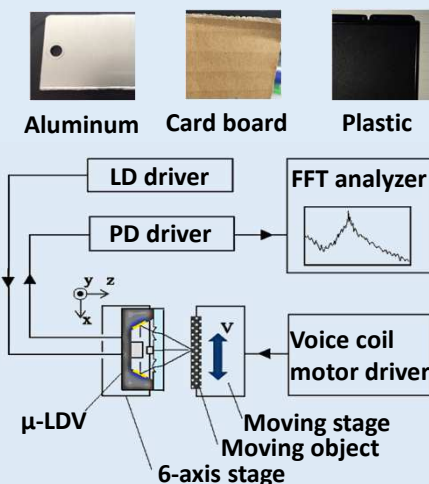


## A-A' Cross section



Initial product : Included in TO-5 without TSV structure

## Experiment & Results



Peak frequency  $\propto$  Velocity

Not affected by material

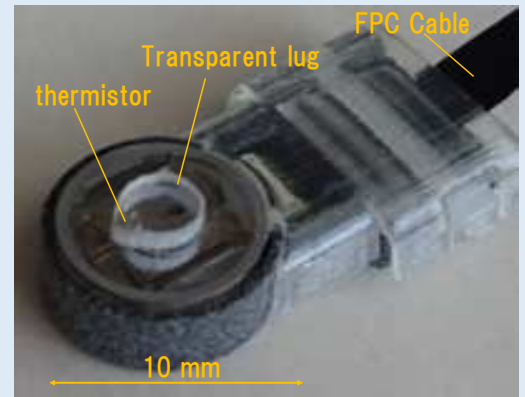
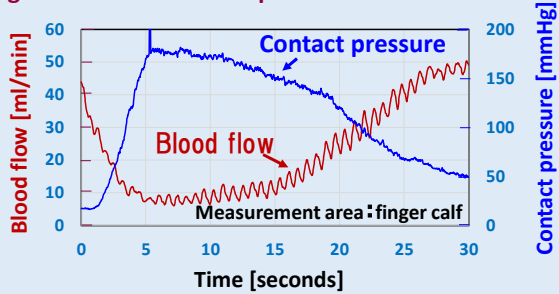
# Blood flow sensor with a built-in contact pressure sensor

## Significance of blood flow measurement

Since blood flow carries oxygen, nutrients, heat and information related to the physiological state of the body and autonomic nerves to the tissues in every corner of the body, measurement of the blood flow is very important.

## Significance of contact pressure measurement

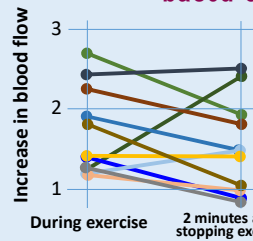
Since blood flow is greatly affected by contact pressure, measurement of blood flow taking into account contact pressure is essential



Blood flow sensor with built-in contact pressure sensor and temperature sensor

## Applications

## Detecting individual differences in exercise effects based on changes in blood flow



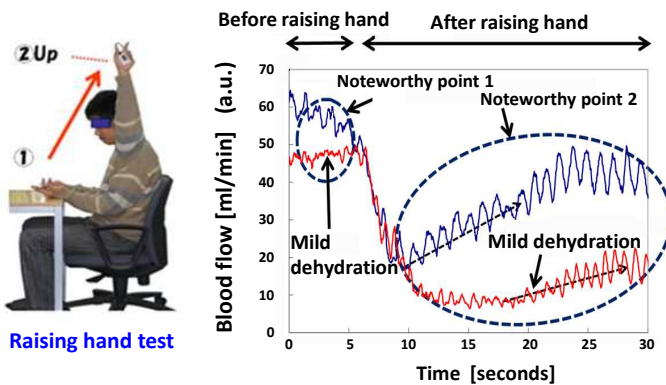
Changes in blood circulation during and after exercise are important for understanding individual differences in the effects of exercise

For most people, the average blood pressure and average heart rate during exercise and 10 minutes after exercise increased compared to before exercise. However, the stroke volume calculated by blood flow sensor showed individual differences✖.

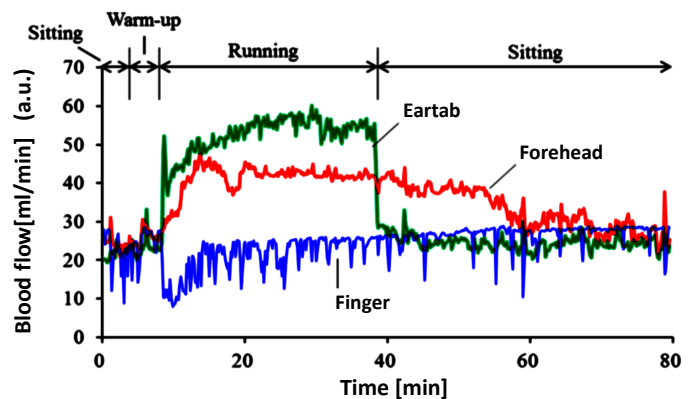
✖ Individual differences have also been observed in stroke volume. Which is determined by measuring the change in the volume of the left ventricle during expansion and contraction using ultrasound echo.  
Stroke volume = the amount of blood pumped by the heart per beat = diastolic volume of the left ventricle - the systolic volume ∝ Blood flow measured by blood flow sensor Q(ml/min)/ Heart rate HR(/min)

Reference: Watanabe K et al., Individual differences in the heart rate response to activation of the muscle metaboreflex in humans, Am J Physiol Heart Circ Physiol, 299, 2010, H1708-H1714.

## Detecting dehydration and heat stroke



## Measurement blood flow while jogging



## Application to oriental medicine

When touching the acupressure points on the soles of the feet

## Simultaneous measurement of blood flow and contact pressure

