An image-sensor-based optical receiver fabricated in a standard 0.35-μm CMOS technology for free-space optical communications
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ABSTRACT
We have developed an image-sensor-based optical receiver for free-space optical communications. In our scheme, each pixel has a function of an optical receiver as well as an image sensor. The functional mode can be selected pixel by pixel. The position of a communication target is detected from the image captured in the image sensor mode. Then, functional mode of the pixel receiving optical signals is changed to the optical receiver mode to start communication. We designed and fabricated a 50x50-pixel photo receiver in a standard 0.35-μm CMOS technology, and fundamental operations were successfully verified. Total transimpedance gain of more than 200 kΩ and data rate of 30 Mbps and 50 Mbps for wavelength of 830 nm and 650 nm, respectively, were obtained.

INTRODUCTION
We are developing a new CMOS image sensor working as an optical receiver in local infrared communication for mobile applications. Recently, IrDA[1] attracts great attention in the application filed of local communication between mobile appliances such as mobile phones and personal data assistants. To aim at post-IRDA with intelligent node detection and concurrent communication between multiple appliances, we have proposed a new scheme of infrared communication based on a special CMOS image sensor realizing intelligent and high-speed communication[2]. In this paper, we show the results of a preliminary CMOS image sensor fabricated in a 0.35-μm CMOS technology.

ARCHITECTURE OF IMAGE SENSOR
In our scheme, an image sensor, which is composed of a large number of micro photodiodes, is utilized as a photoreceiver as well as a position-sensing device, although a single photodiode is used in the conventional IrDA scheme. The use of image sensor has promising potentialities; because it can capture the scene around the communication node or hub at once like ordinary image sensors, it is easy to implement detection and tracing of the communication nodes or hub without any mechanical devices to search them. Figure 1 shows light detection scheme using an image sensor and the block diagram of the proposed image sensor. The proposed image sensor can select two functional modes pixel by pixel: image sensor and communication modes. In the image sensor mode, it woks as an ordinary CMOS image sensor, and the positions of the other appliances are detected from the captured image. Instead in the communication mode, optical signals are directly readout from the pixels receiving it without integrating photocurrents. By making best use of advantages of the image sensor, communication area can be widened without reducing communication bandwidth, and concurrent communication between multiple appliances will be possible.

DESIGN AND EXPERIMENTS
We have designed and fabricated a pixel TEG and a 50x50-pixel image sensor in a standard 0.35-μm CMOS technology. Figure 2 shows the block diagram, and specifications are summarized in Table 1. Because a light spot is often received by multiple pixels, mechanism of summation of amplified photocurrents is prepared.(Fig. 3) Figure 4 shows schematics of the pixel and the column-parallel main amplifiers. The pixel amplifier is composed of an inverter-based transimpedance amplifier[3] and voltage-current converter. The gain is controlled by VTUNE. The main amplifier consists of a folded-cascade transimpedance amplifier and a gain stage composed of a successive two differential pairs. From the experimental results shown in Fig. 5, we have confirmed that two functional modes can be switched correctly. Data rate of 50 Mbps was achieved for wavelength of 650 nm. As shown in Fig. 6, gain penalty for wavelength 830 nm was about -1 dB comparing with wavelength of 650 nm due to diffusion carriers. Therefore, data rate decreased down to 30 Mbps for wavelength of 830 nm.

CONCLUSIONS
CMOS-image-sensor-based optical receiver for local infrared communication between mobile appliances was proposed. We fabricated a test pixel circuit. From the experimental results, fundamental operations of the test pixel circuit and the 50x50-pixel image sensor in the image sensor and communication modes were confirmed.

ACKNOWLEDGEMENTS
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REFERENCES
Fig. 1. Detection of positions and optical signals scheme using an image sensor.

Fig. 2. Block diagram of the proposed image sensor.

Fig. 3. Summation of amplified photocurrents and read-out through column-parallel main amplifier.

Fig. 4. Schematics of (a) pixel and (b) column-parallel main amplifier.

Fig. 5. (a) An example of the captured image and (b) 50 Mbps eye diagram for wavelength of 650 nm.

Fig. 6. Experimental results of frequency responses.

Table 1. Specifications of the CMOS image sensor in a standard 0.35-µm CMOS technology.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Chip size</td>
<td>4.9 mm sq.</td>
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<tr>
<td>Number of pixels</td>
<td>50 x 50</td>
</tr>
<tr>
<td>Pixel size</td>
<td>60 µm sq.</td>
</tr>
<tr>
<td>Fill factor</td>
<td>16%</td>
</tr>
<tr>
<td>Data rate</td>
<td>30 Mbps$\lambda=830$nm, 50 Mbps$\lambda=650$nm</td>
</tr>
<tr>
<td>Total transimpedance gain</td>
<td>&gt;200 kΩ (variable)</td>
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