Electromagnetic Field Visualization System for IC/Package Design Based on Optical Techniques

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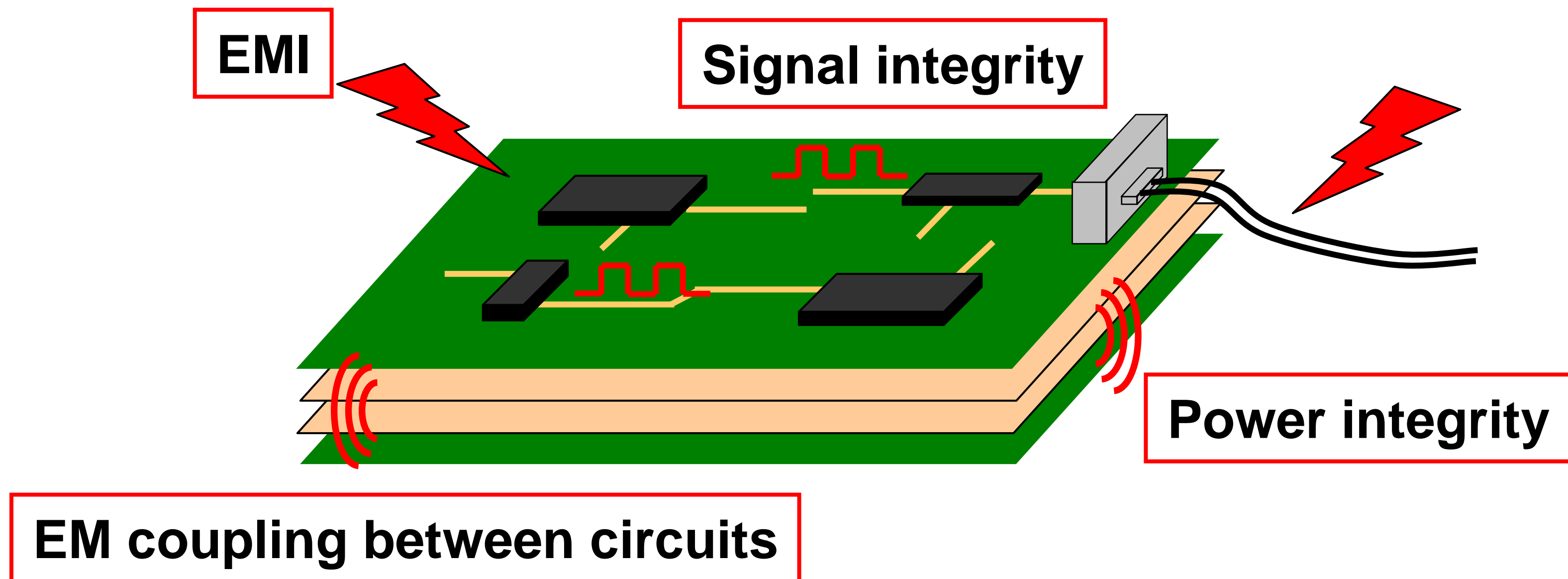
Background and motivation

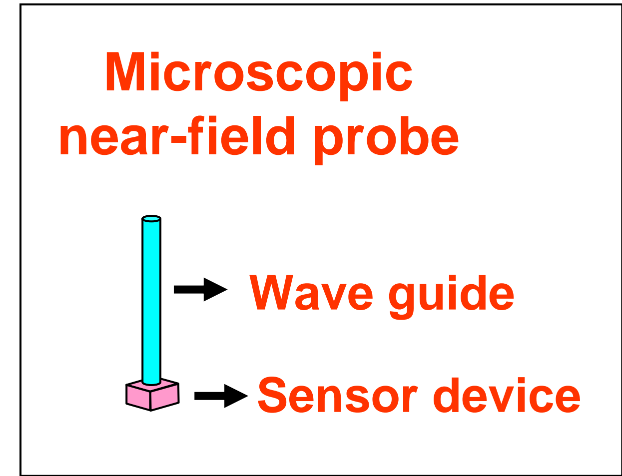


It is highly desirable to prevent the problems in the early stages of design and packaging of electronic components.

Background and motivation

Conventional circuit performance evaluation/testing techniques such as a network analyzer and a TDR

- **It is difficult to identify the concrete location of the faulty components inside the circuits.**
- **They cannot give direct information about an EM coupling position and individual decoupling capacitor performance.**



Decoupling capacitor

Die

Die

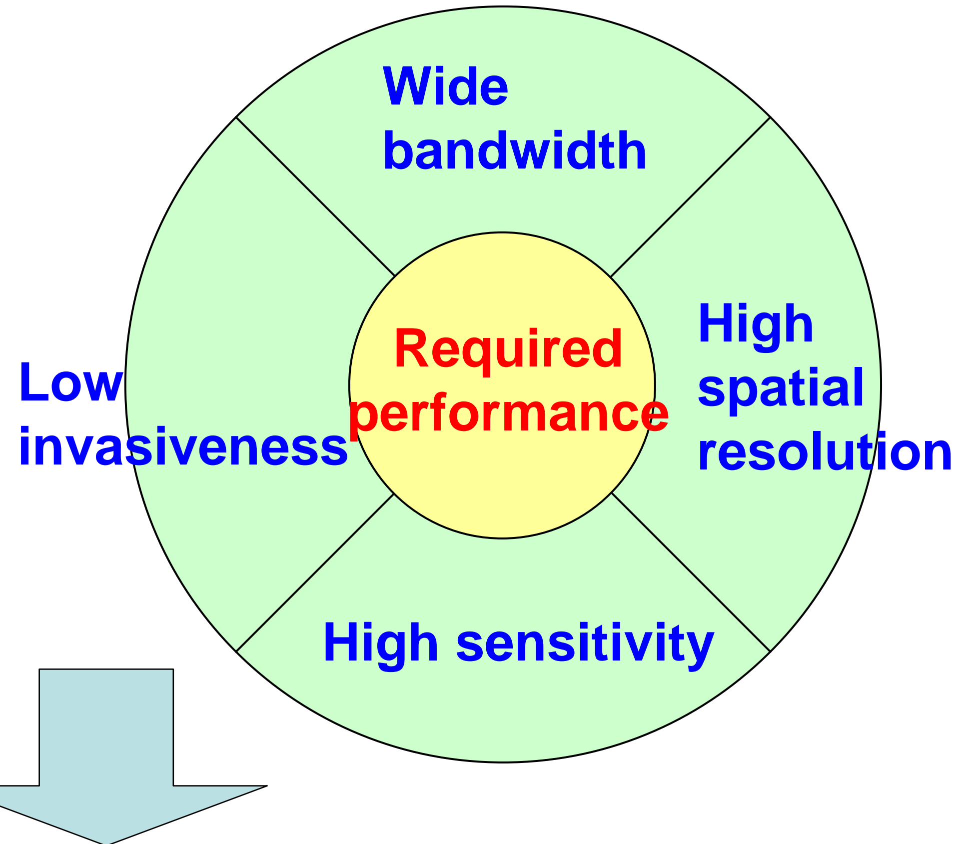
Ground

Power

Interposer

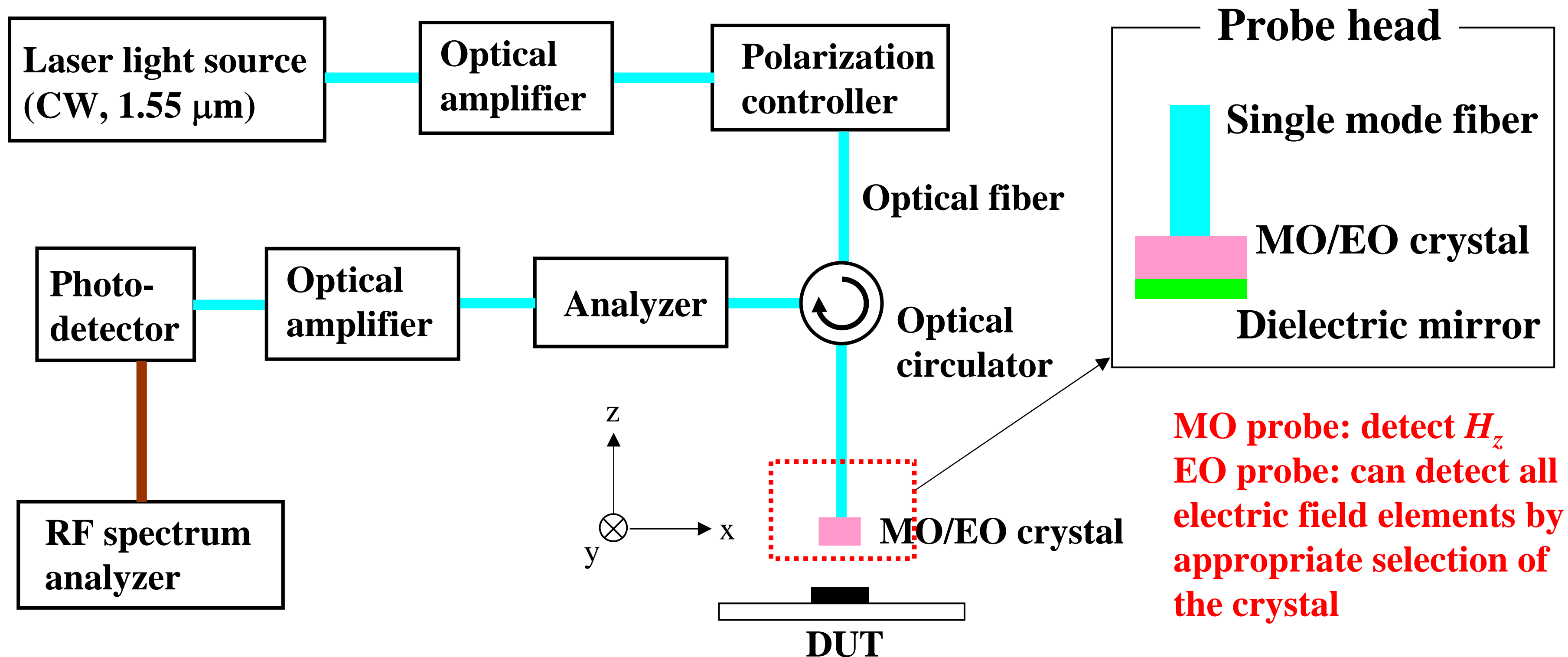
Background and motivation

Near-field probing technique is one of indispensable techniques.



Development and evaluations of a near-field probe that utilizes optical measurement techniques.

FEMO/EO probing system



- **All apparatuses in the optical system are connected by optical fibers.**
  → **Free from optical alignment**
- **The probe head consists of an optical fiber and a minute crystal.**
  → **Superior low-invasiveness**
  → **High spatial resolution**

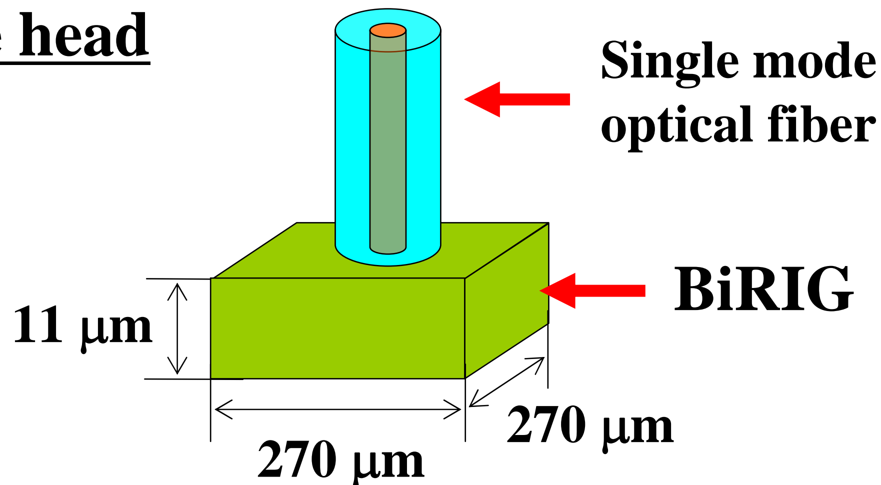
Objective

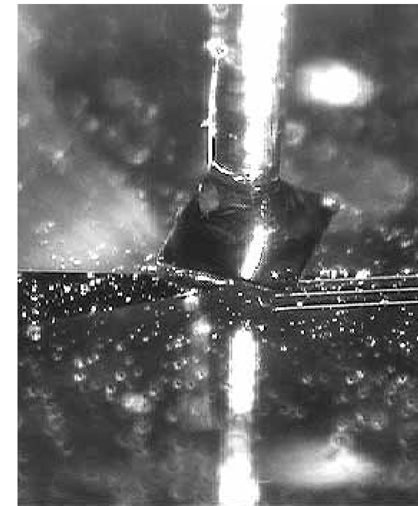
Development and application of high performance near-field probing system toward the high-speed and low-noise design of ICs/packages.

Magnetic near-field maps over fine meander circuits

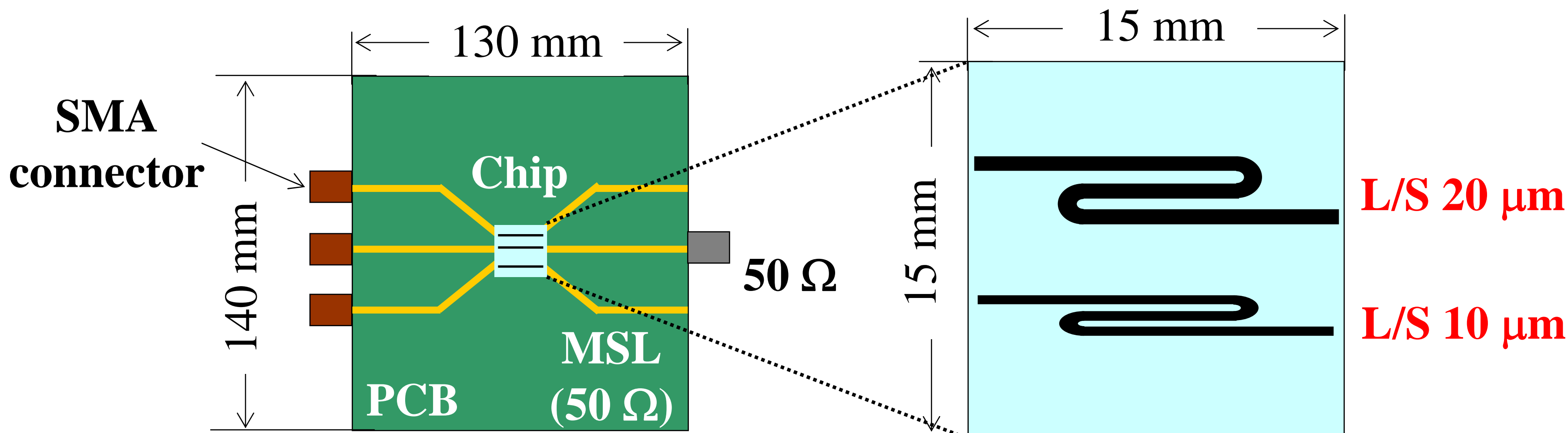
Probe head and device under test (DUT)

Probe head





DUT for near-field mappings



Frequency response of the FEMO probe

2.5 GHz

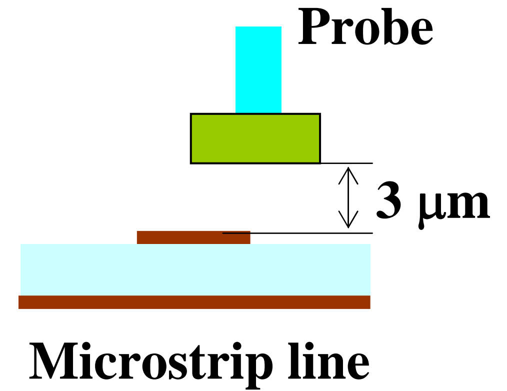
-80
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130

MO Signal [dBm]

Noise level

10
100
1000
10000

Frequency [MHz]

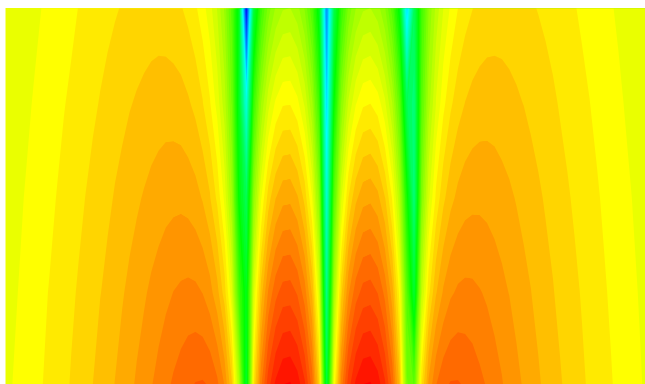


The range where the signal level undulation stays within 3 dB. **2.5 GHz**

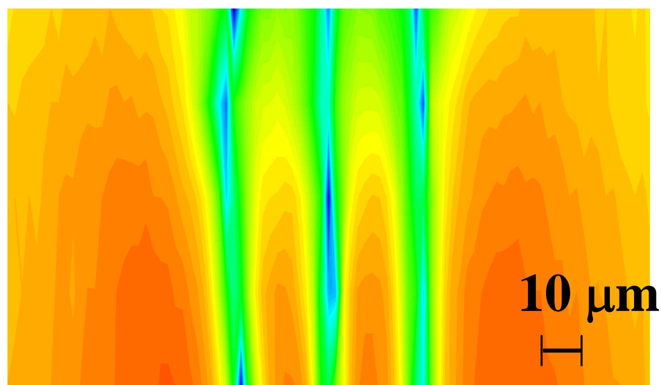
X-Z near-field maps

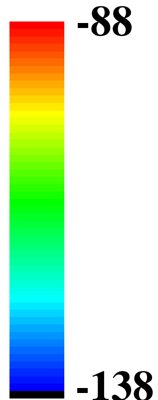
10 MHz

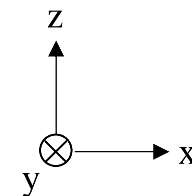
Cal.

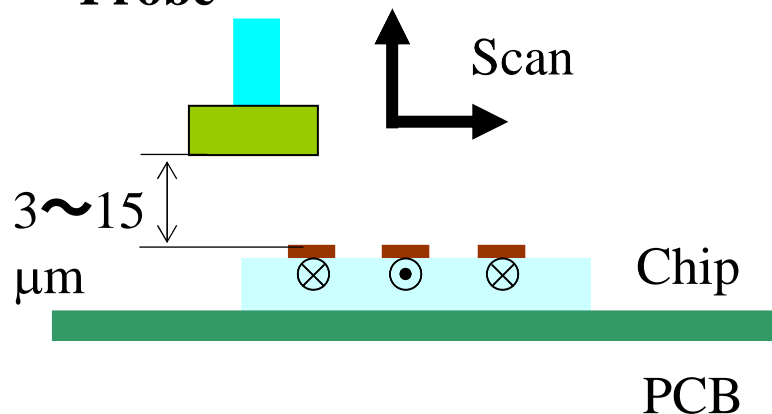


Exp.







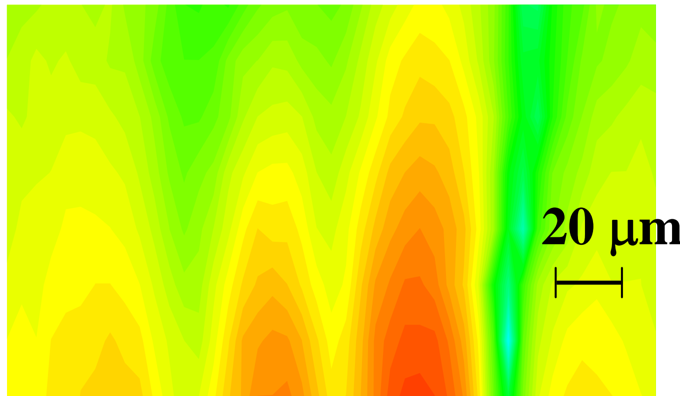


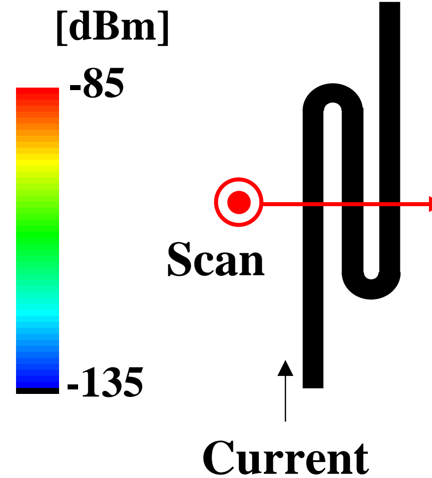
Line/Space 10 μm

X-Z near-field map

1 GHz

Exp.

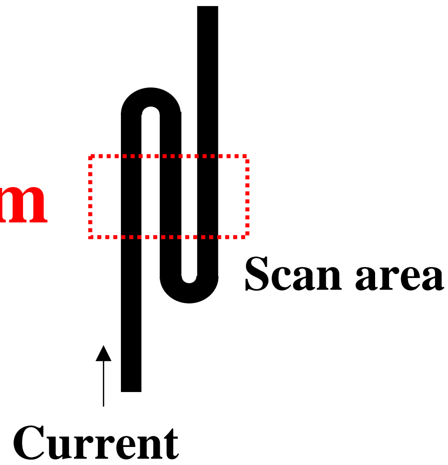


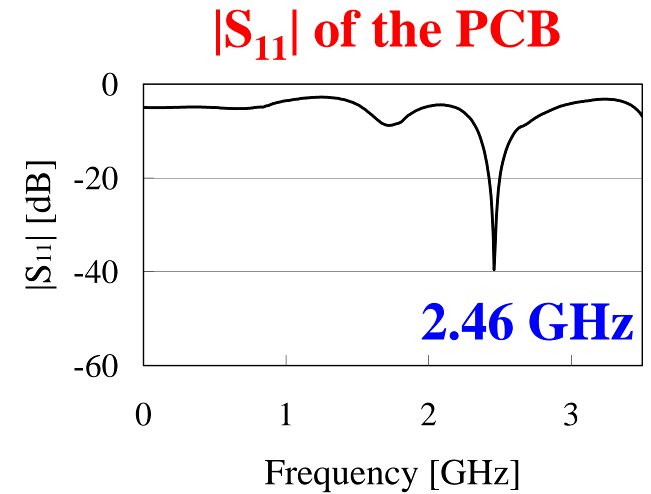


Line/Space 20 μm

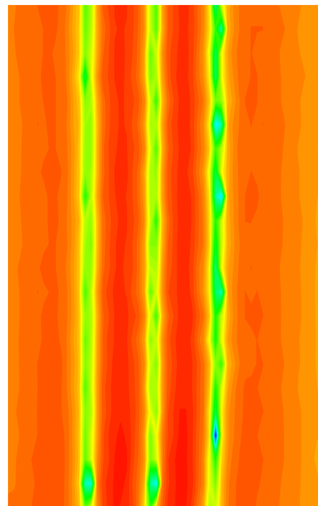
X-Y near-field maps

Line/Space 20 μm





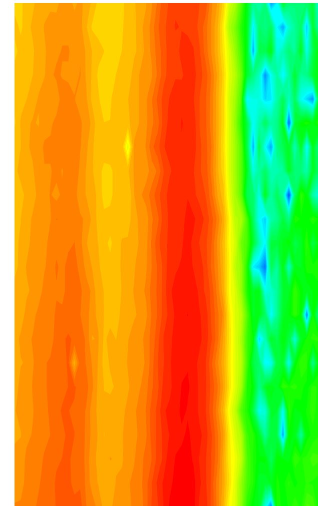
10 MHz



[dBm]
-85
-145

50 μm

2.46 GHz



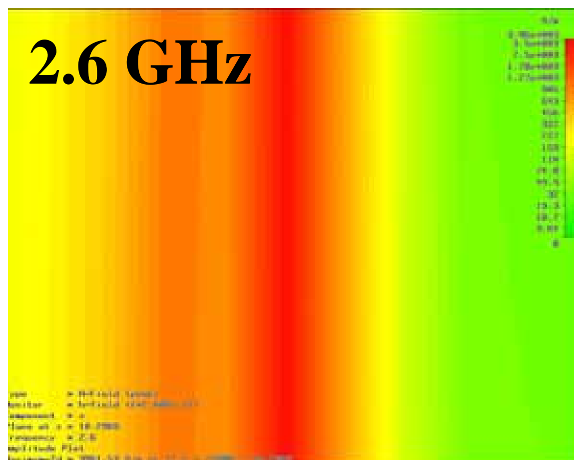
[dBm]
-90
-150

Verification of measured results by electromagnetic field simulator

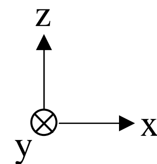
Simulated maps of the amplitude of H_z at nearby the middle position of the circuit.

X-Z map

X-Y map



These results suggest that the measured near-field maps are accurate.



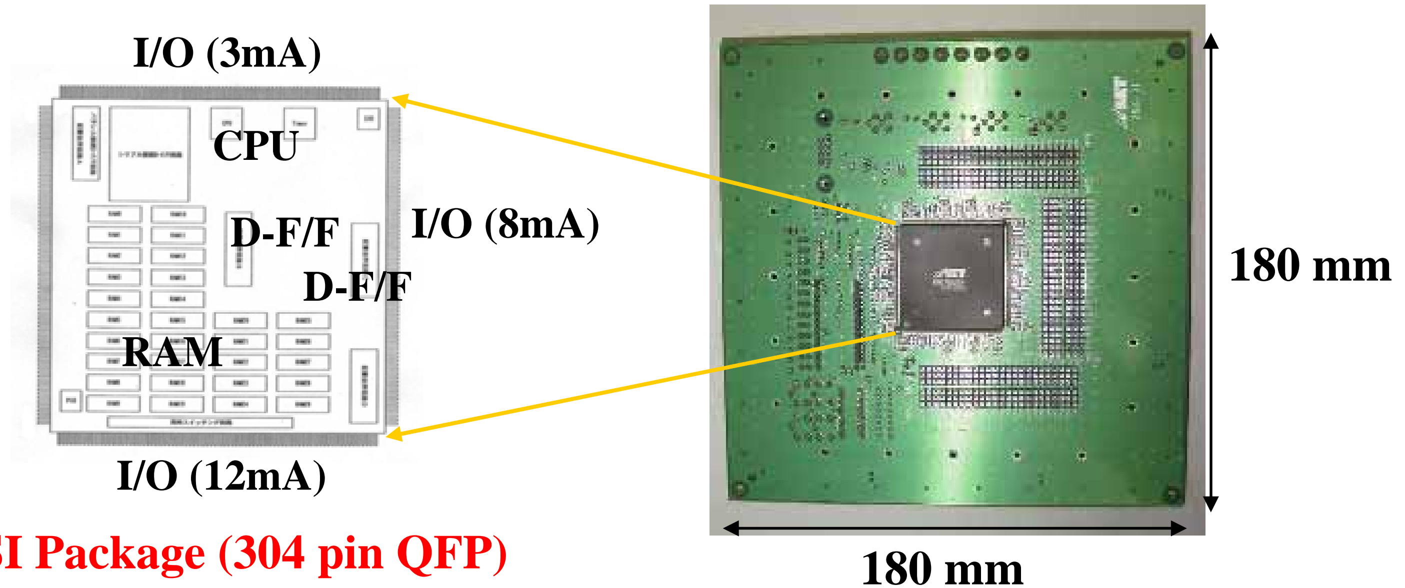
Line/Space 20 μm meander circuit

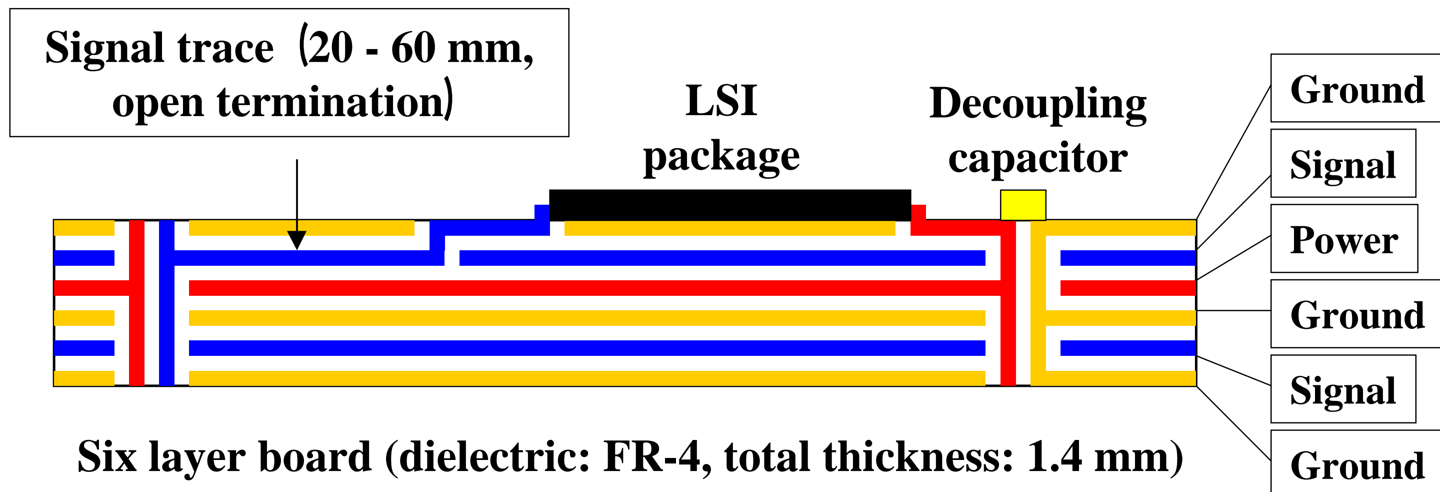
dielectric

Ground plane

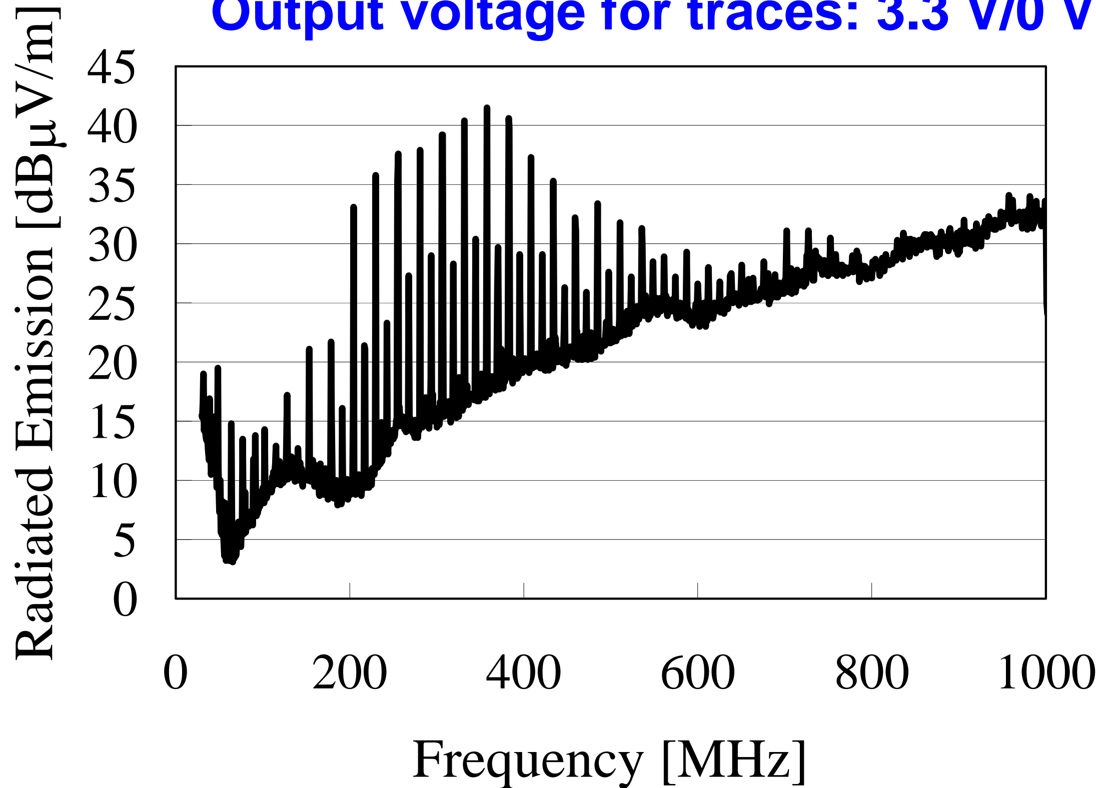
Electromagnetic near-field measurements over active devices

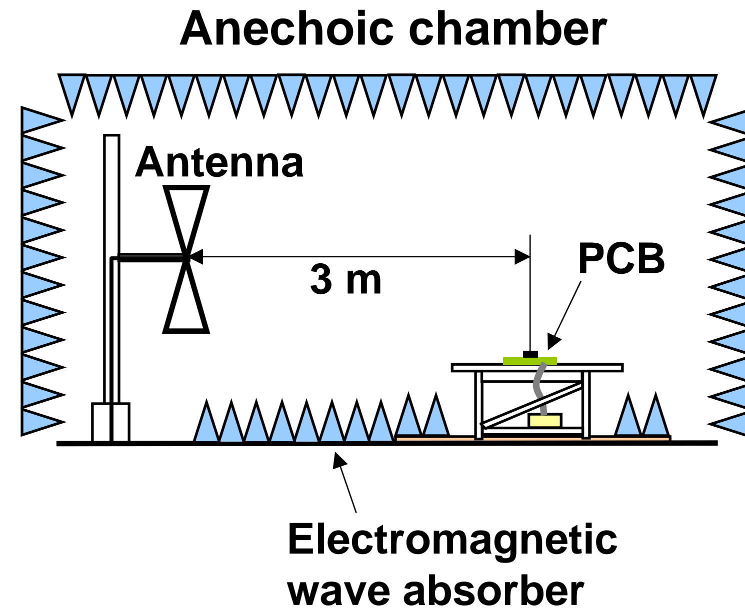
DUT for near- and far-fields evaluations





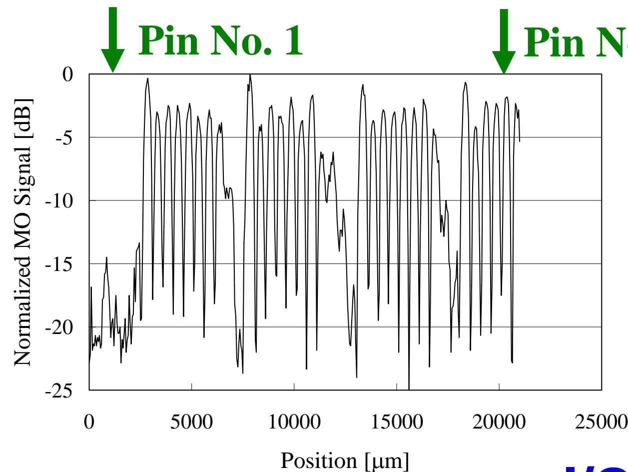
Radiated electric field strength



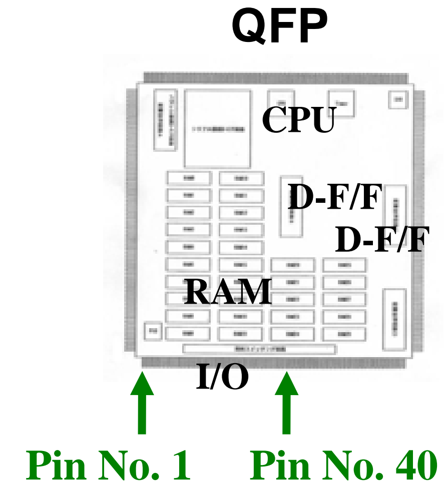


High-level emissions are observed at 12.75 x 2n MHz.

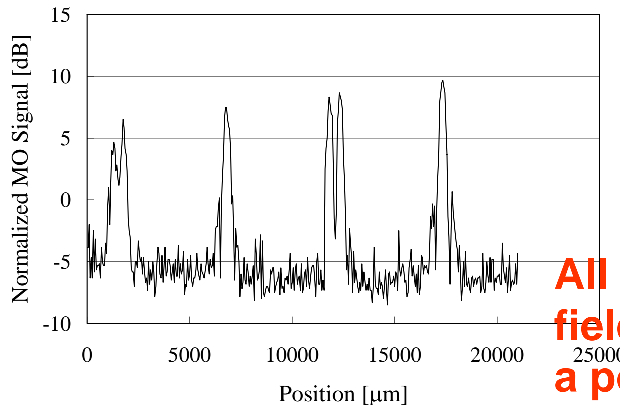
Magnetic near-field distributions over the LSI package pins



12.75 MHz

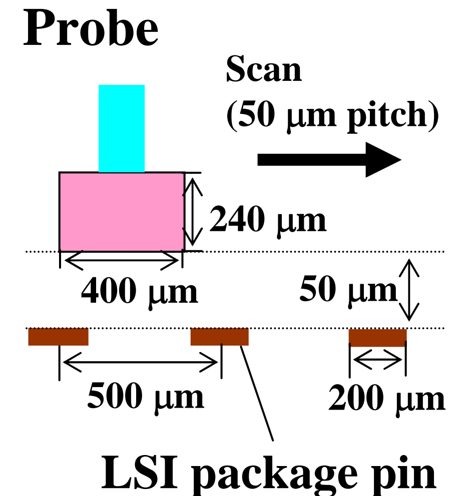


I/O circuit operation



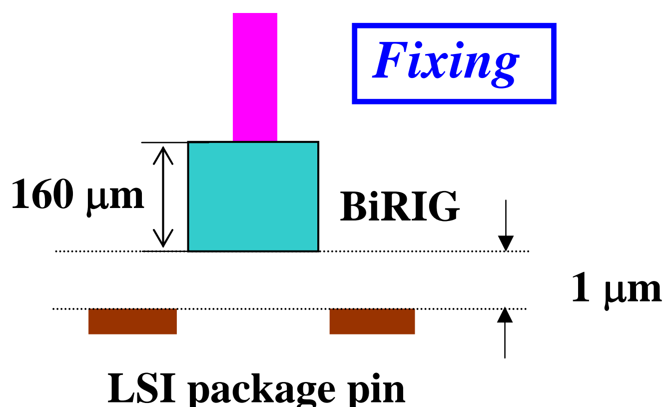
127.5 MHz

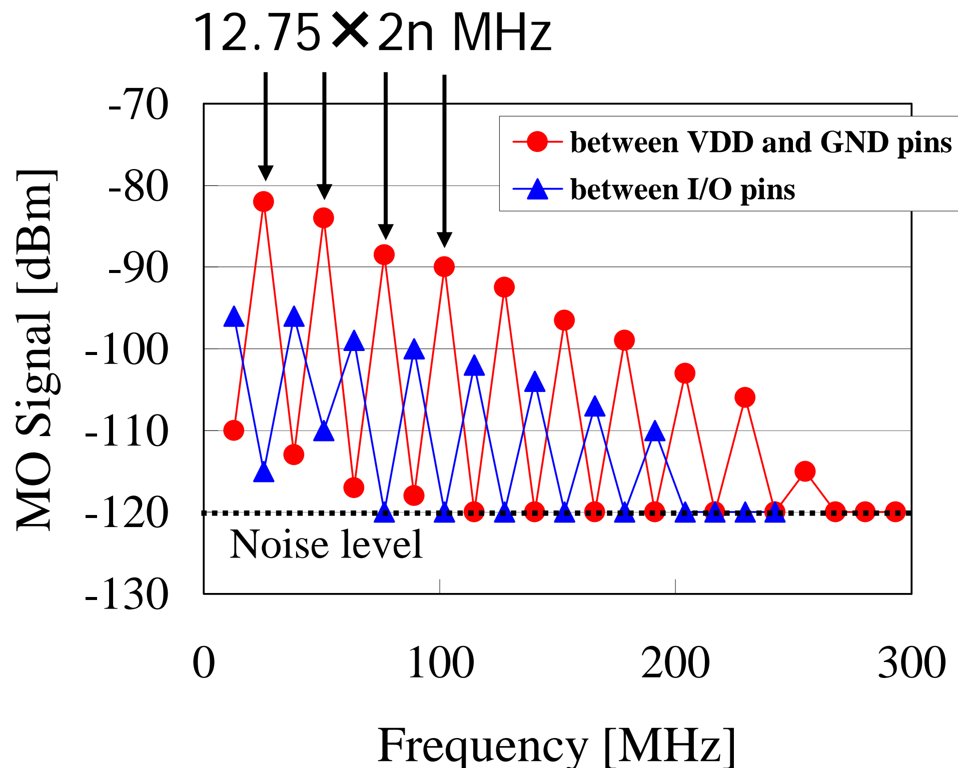
All peaks are due to the magnetic fields generating from the pins for a power or a ground



The probe has the capability for investigating circuit failure and an EMI source.

Frequency dependence of MO signals





Measurement frequencies: multiples of 12.75 MHz

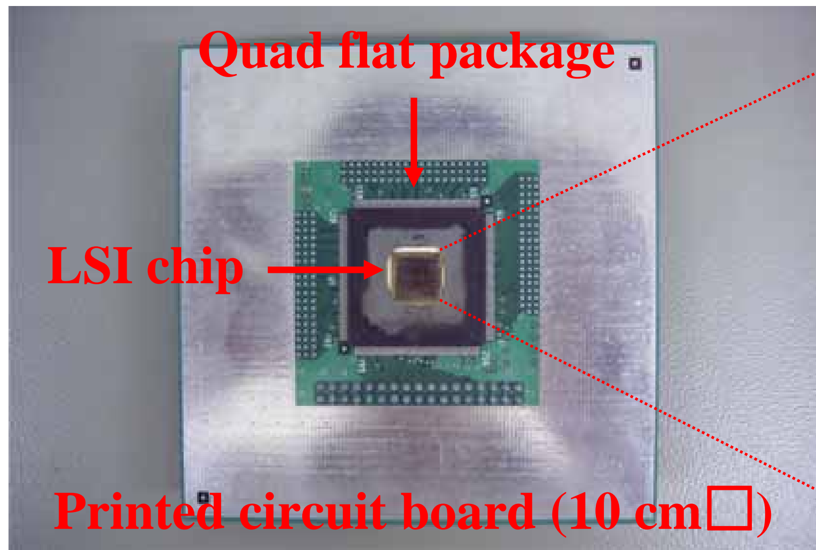
Between power and ground pins: high-level signals are observed at 12.75 x 2n MHz (Same feature as the electric far-field characteristic)

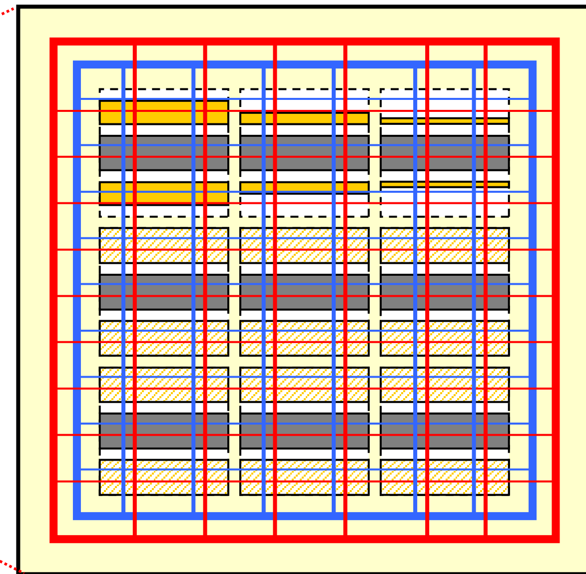
This suggests that the origin of the high-level electric field radiation is a current flowing in the power supply system of the I/O circuits.

LSI chip for near-field measurements

Decoupling capacitor area

Logic circuit area





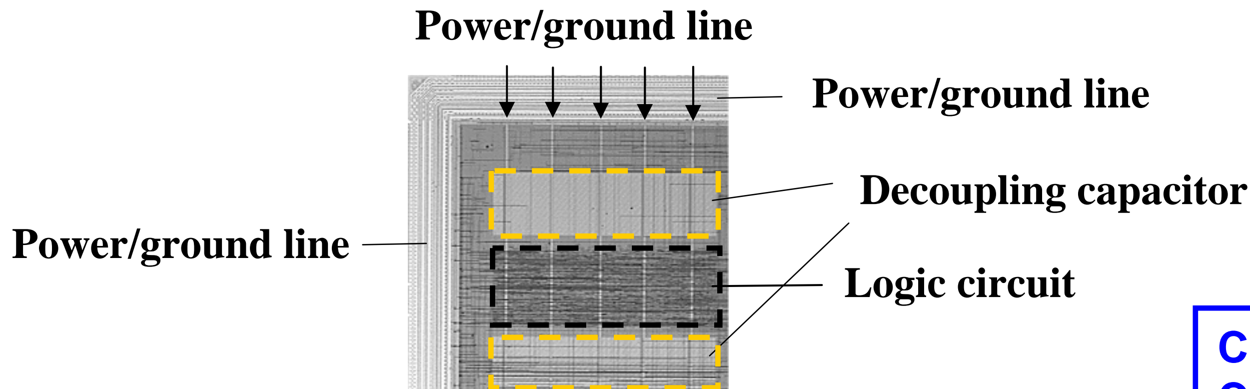
10.4 mm□

Power/ground line for logic circuits

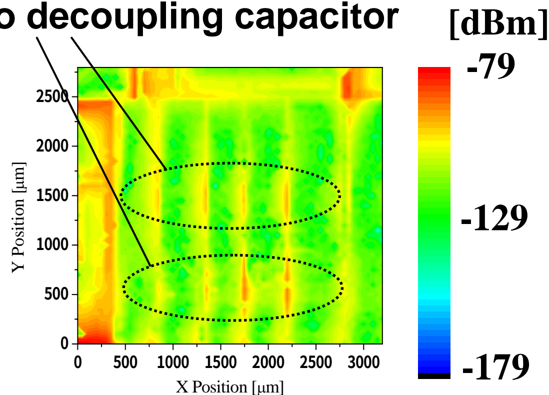
Width of horizontal lines : 1.2 μm

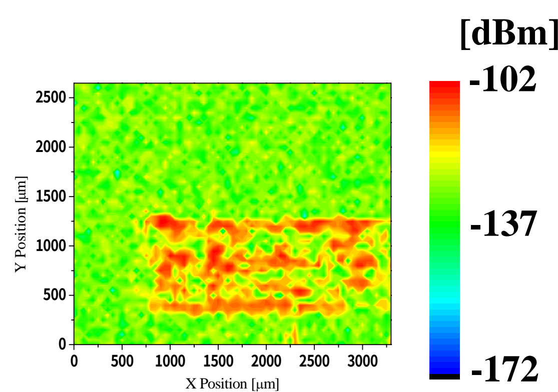
Width of vertical lines : 10 μm

Magnetic/electric near-field maps over an LSI chip



Clock frequency: 50MHz
Circuit operation frequency: 25 MHz
Measurement frequency: 50 MHz





Magnetic field distribution **Electric field distribution**

Magnetic field: strong intensity above the power supply system
Electric field: strong intensity above the signal system
⇒ **This suggests that detail SI/PI analyses can be performed by the EO/MO probing technique.**

Conclusions

- We introduced a wideband MO probe with a 10-μm-class spatial resolution.
- GHz-region magnetic near-fields over a fine circuit were successfully mapped.
- The potential of the probe for near-field characterization and EMI source evaluation of an active device was shown.
- These results demonstrate that the FEMO/EO probing technique can be an effective tool toward an optimum design/packaging of electronic components.

Acknowledgement

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- This work was performed under the guidance and cooperation of Tsuchiya lab of the University of Tokyo.

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