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on Advanced Condition Monitors for Nuclear Power and Other Process Systems

Non-contact Acoustic Emission Measurements for Condition Monitoring of Bearings in Rotating Machines using Laser Interferometry

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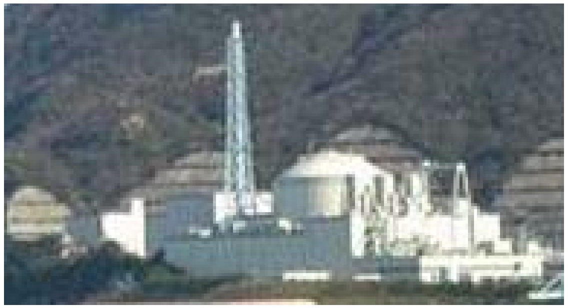
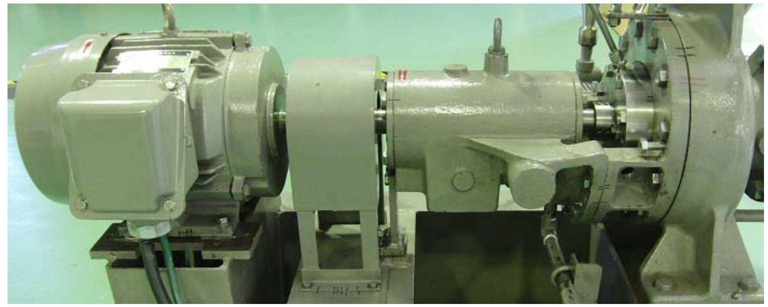
Backgrounds

Condition Based Maintenance (CBM)



Nuclear power plants



An example of pump

Rolling bearing

Target equipments

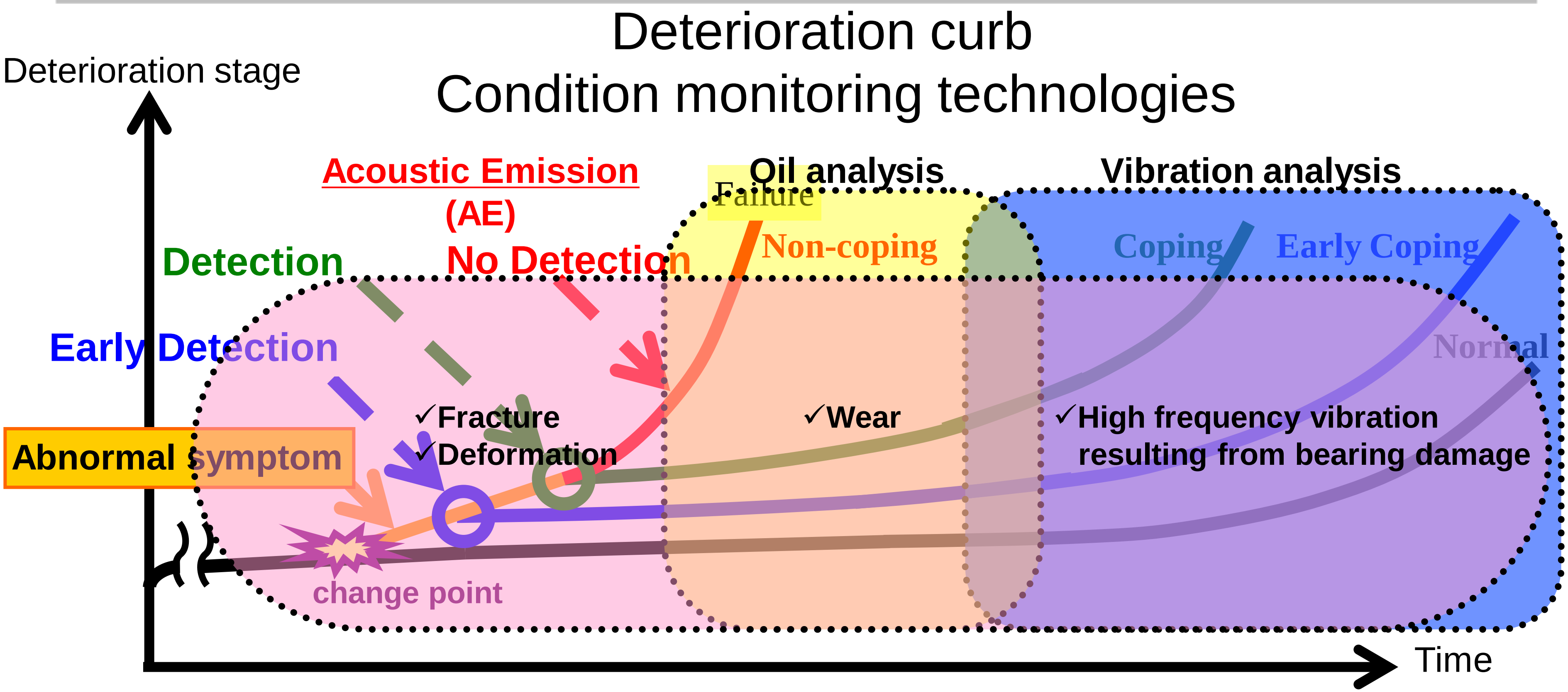
- Pumps
- Valves
- Piping

Pumps → Main failure mode

- ✓**Rolling bearing damage**
- ✓Misalignment
- ✓Unbalance

Rolling bearings are one of the most important targets of condition monitoring in nuclear power plants.

"When and How" for an earlier detection of abnormal symptoms

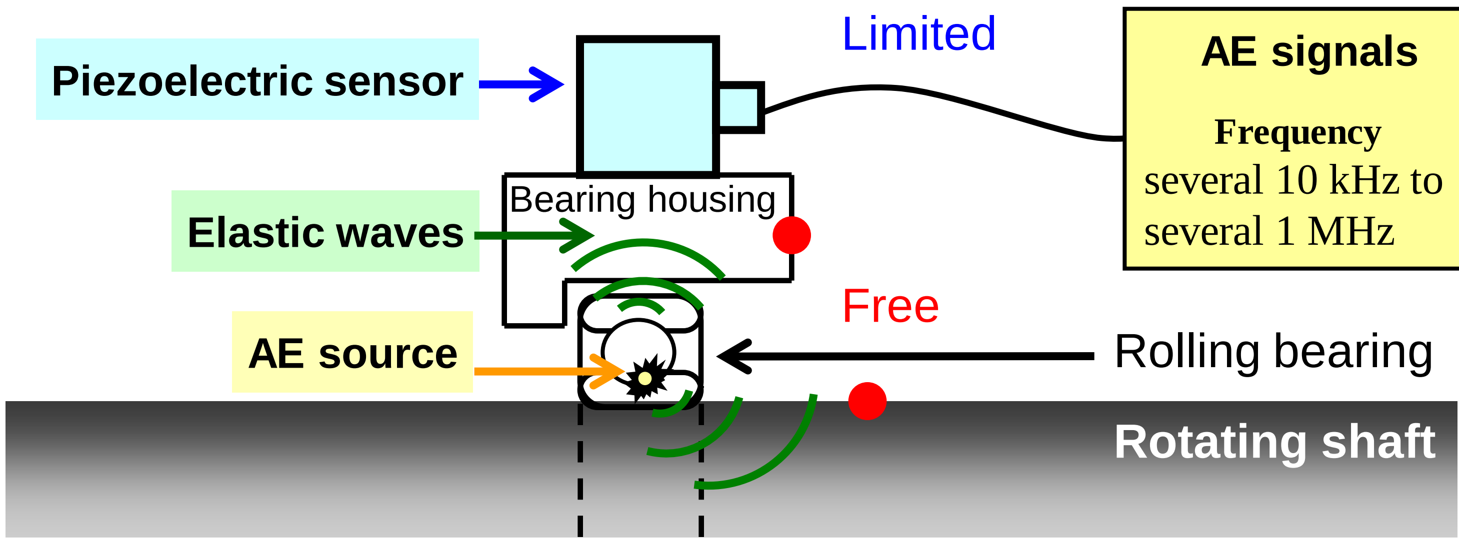


✓**In order to maximize bearing life, it is important to detect abnormal symptoms as early as possible.**

✓**AE is the most useful method for understanding abnormal states and deterioration symptoms of bearings.**

AE (acoustic emission) method and sensor types

AE method



AE sensor types

	Measurement method	Measurement point	Noise in rotating machines
Contact type	Piezoelectric sensor Optical transducer	Limited	Large
Non-contact type	Laser interferometer [1][2][3]	Free	Small

Previous studies using interferometers have only been applied to the measurement of static objects.

[1] Palmer（1977）, [2] Bruttomesso et al.（1993）, [3] Watanabe et al.（2003）

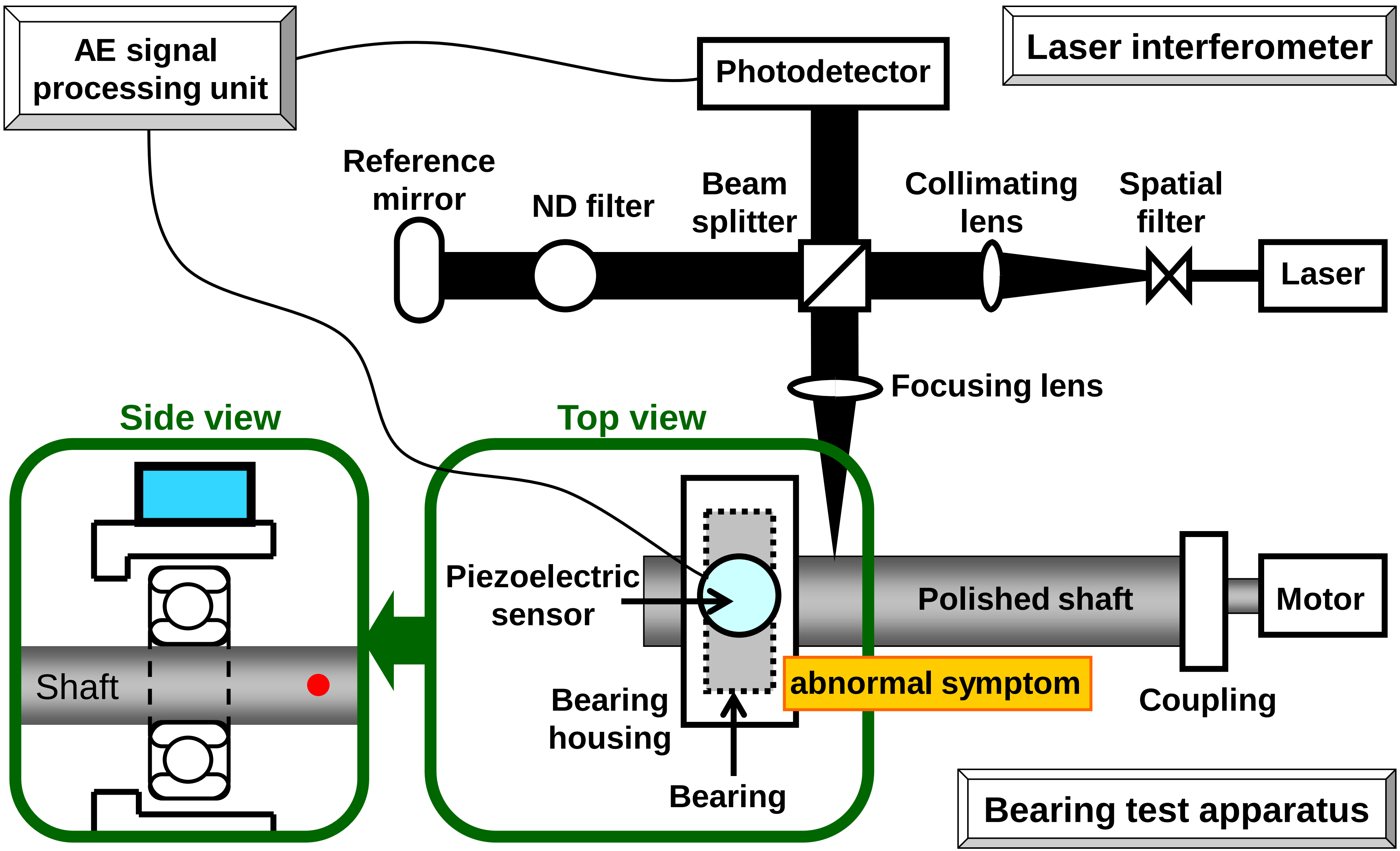
Work plan

- ✓Setup a rotating shaft laboratory test using bearings with artificial-defects
- ✓Setup a laser interferometer which can detect AE propagated on the rotating shaft
- ✓Select the most adequate AE parameters corresponding with changes of bearing defect size

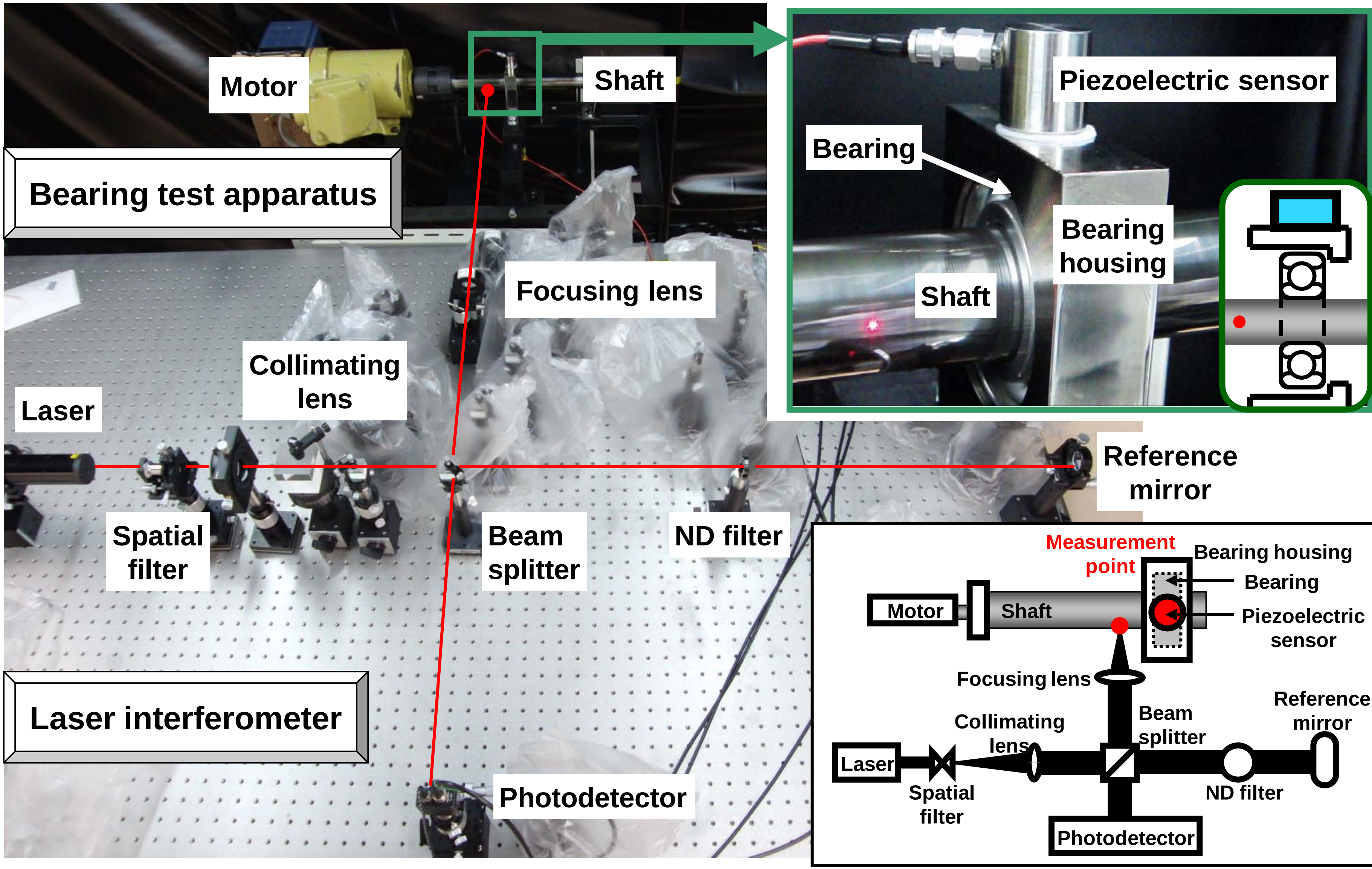
Long term goal

To be applied to condition monitoring technology in actual plants

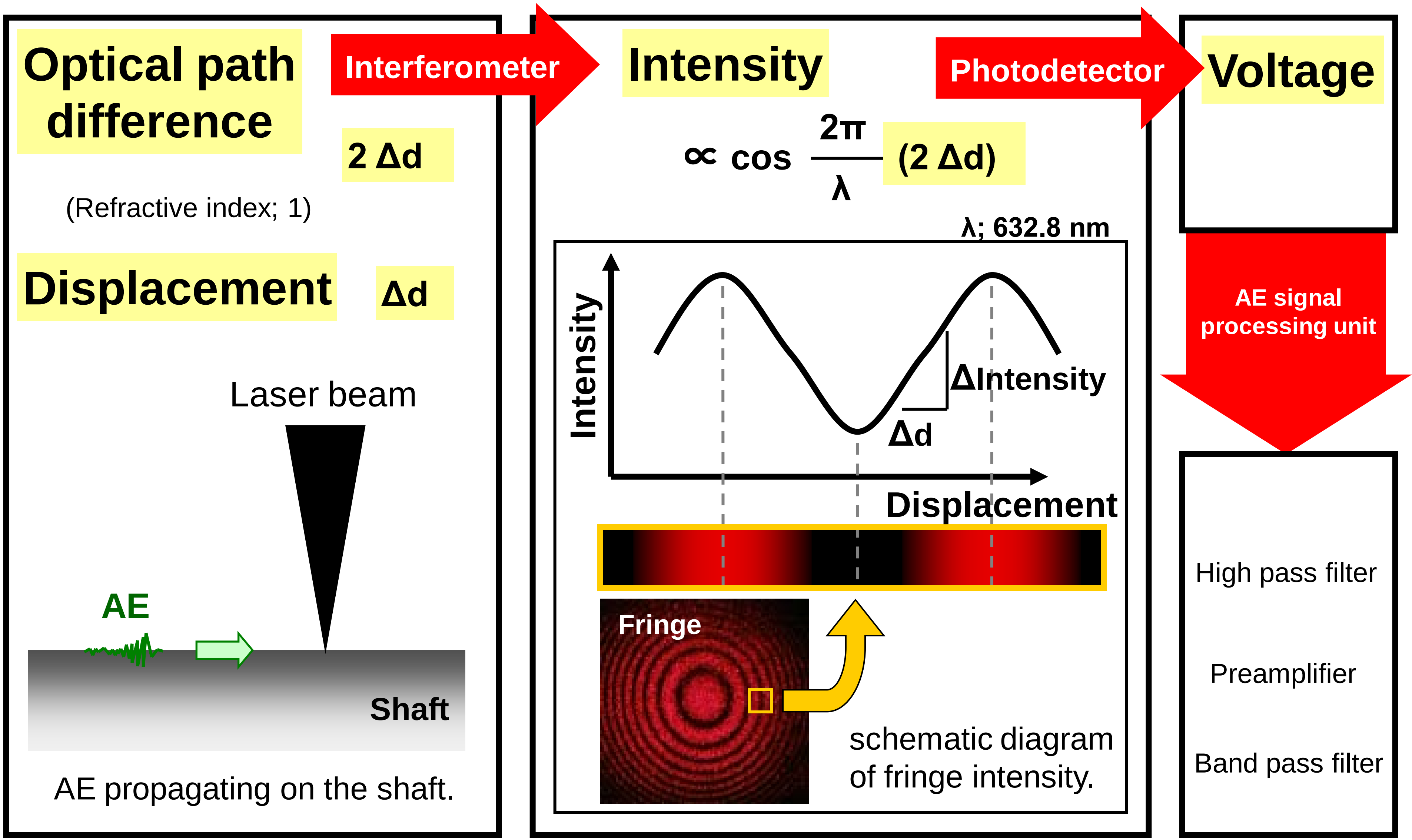
Configuration of the experimental setup



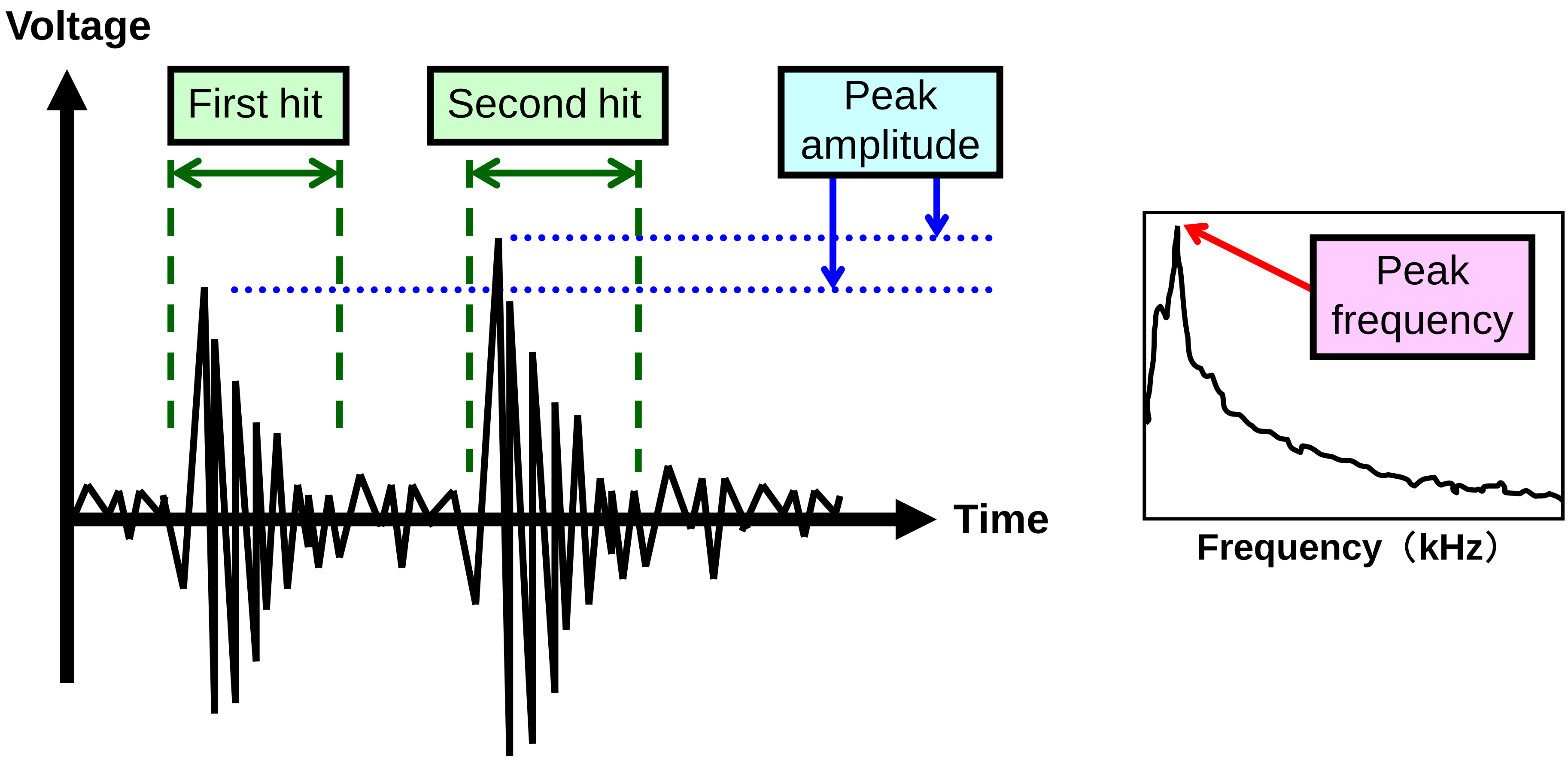
Overview photograph of the experimental setup



Conversion of AE into voltage (simplification)



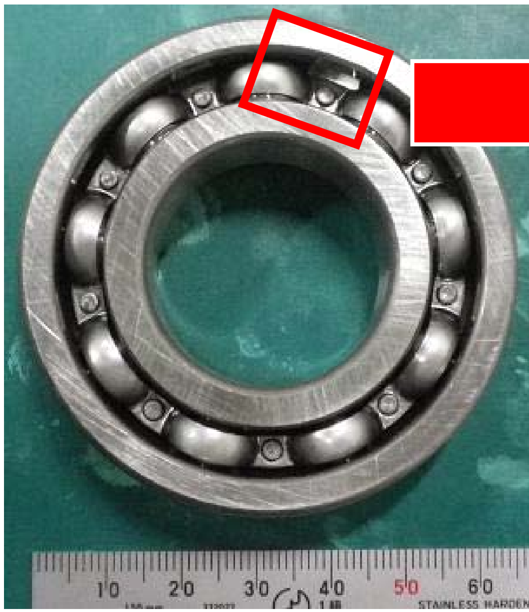
AE parameters



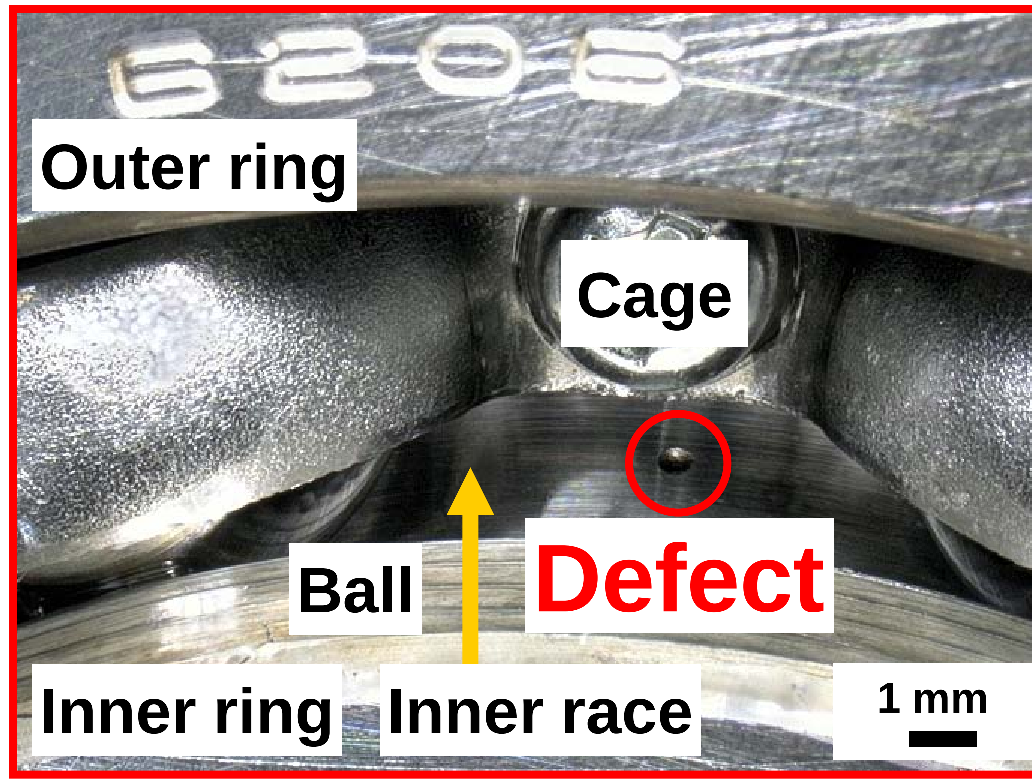
Schematic AE signals (left side), and a power spectrum (right side) obtained from one AE wave packet.

Bearing specimen

6206 deep-groove ball bearing



inner diameter 30 mm
outer diameter 62 mm
width 16 mm
balls diameter 9.53 mm



An example of a φ0.50 mm artificial defect, which has been added on the inner race by electric discharge machining.

Test conditions

- **Defect size of bearing specimen** (depth; 0.25 mm)
  defect-free,
  φ0.25 mm, φ0.50 mm, φ0.75 mm, φ1.00 mm
- **Rotational speed**
  837 rpm
- **Total number of rotations**
  100,000 (about 120 minutes)
- **Measurements using two different methods:**
  ✓ rotating shaft using presented laser interferometer
  ✓ bearing housing using piezoelectric sensor
- **Threshold on each measurement point**
  ✓ 62 dB_{AE} at rotating shaft
  ✓ 70 dB_{AE} at bearing housing

The reference value of dBAE is 1 μV

Number of AE hits

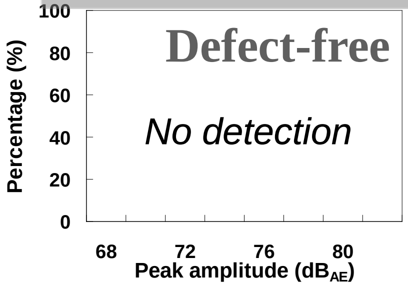
Measurement method	Measurement point	Time (min)	Defect size (mm): -free	ϕ0.25	ϕ0.50	ϕ0.75	ϕ1.00
Laser interferometer	Rotating shaft	**12**	43	609	680	884	1380
		120	1313	5437	6695	8859	13174
Piezoelectric sensor	Bearing housing	**12**	0	3	3	111	188
		120	0	11	26	815	1771

✓**The number of AE hits increases with defect size.**

✓**AE waves are generated stably through the test duration.**

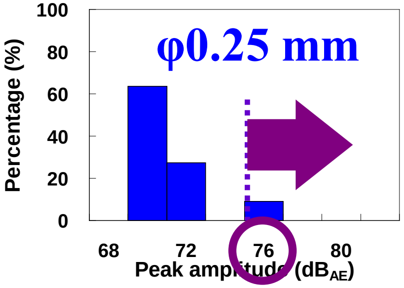
✓**When measuring on the bearing housing, similar trends are observed. However, the number of AE hits is much lower than for shaft measurements.**

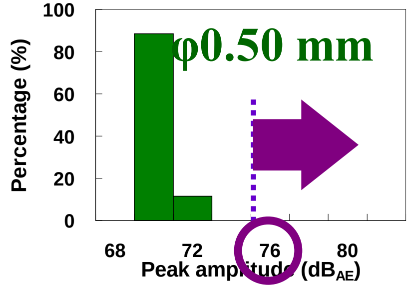
Peak amplitude distribution

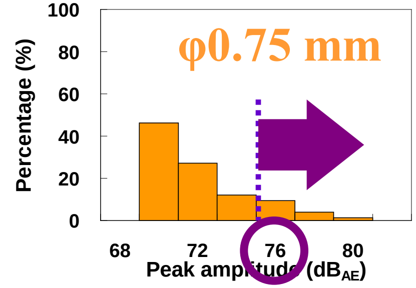


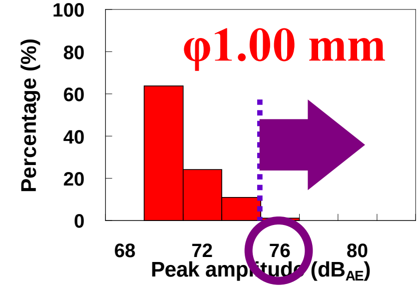
Piezoelectric sensor, bearing housing

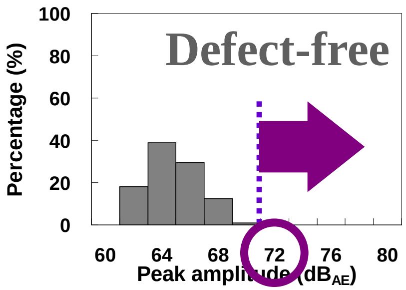
The maximum peak amplitude values change irregularly and are independent of defect size.





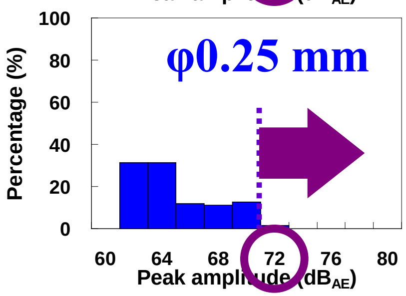


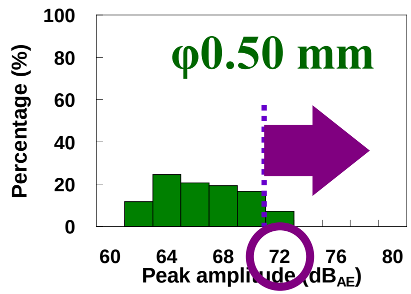


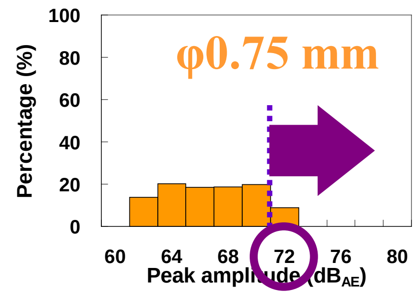


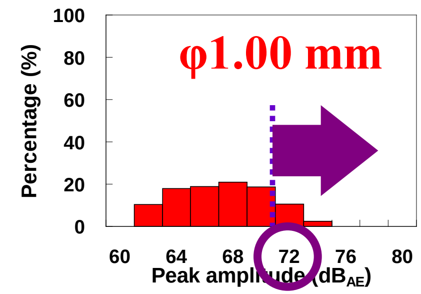
Laser interferometer, rotating shaft

By increasing defect size,
the distribution shifts towards higher amplitudes.
However, the relation is rather weak.



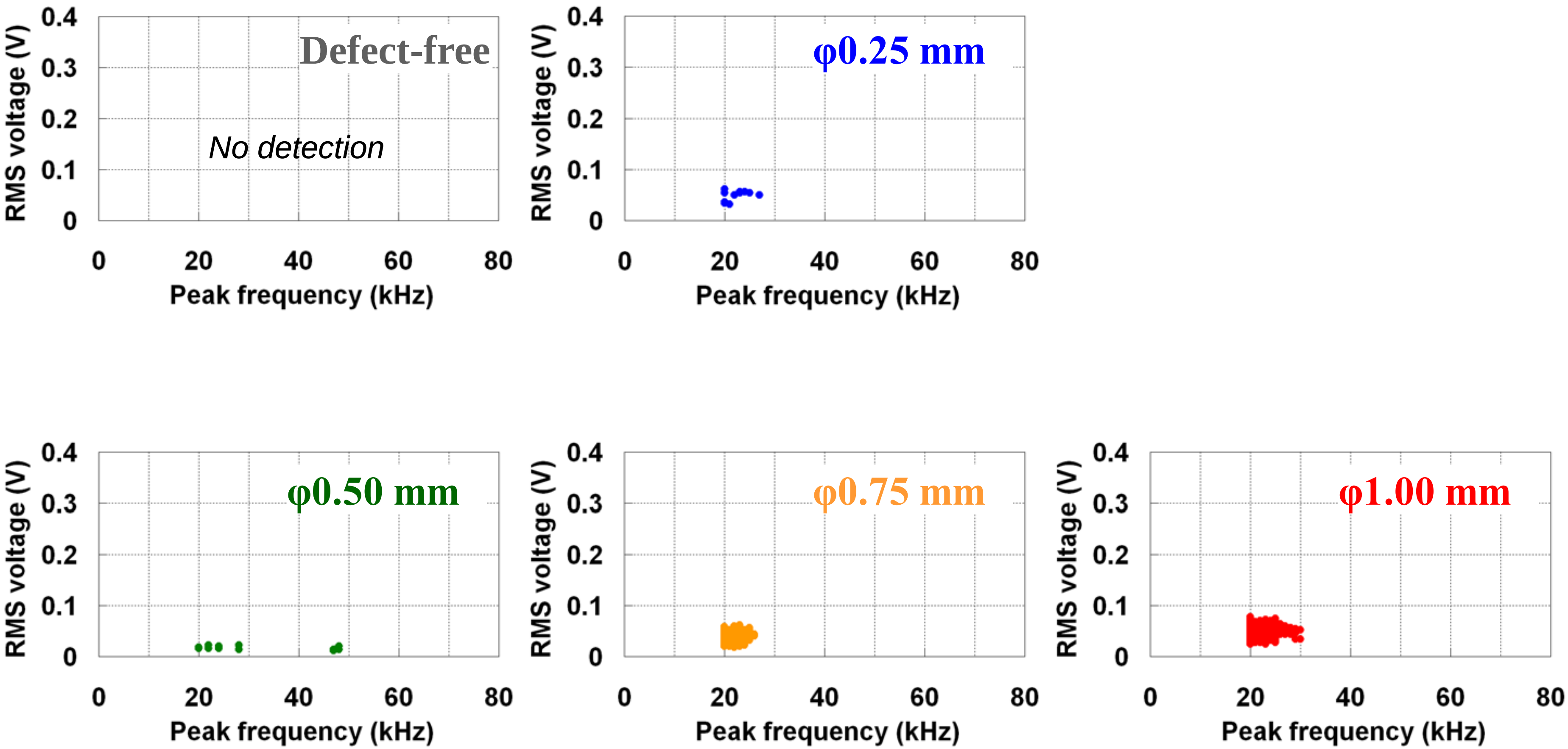






RMS (Root Mean Square) and Peak frequency

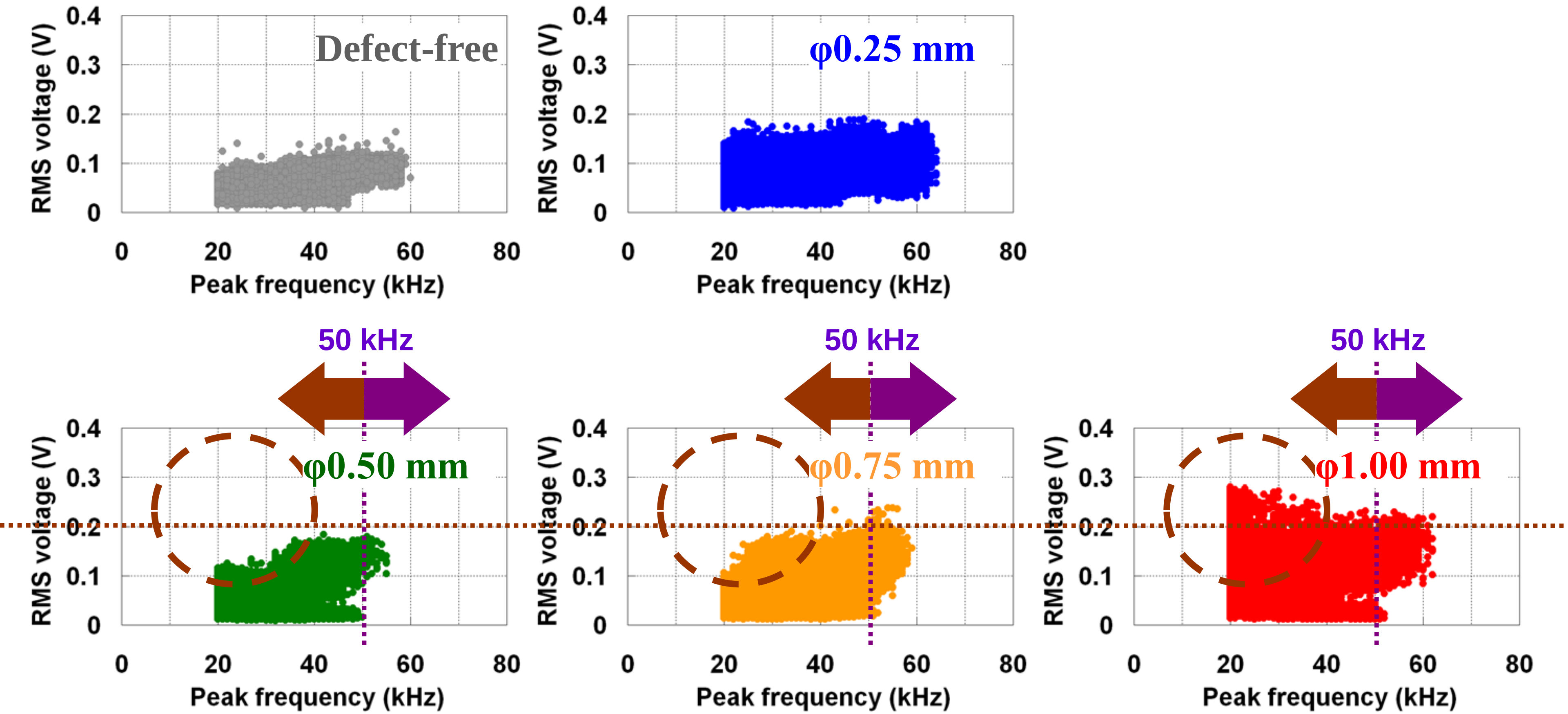
Piezoelectric sensor
Bearing housing



The RMS voltage and the peak frequencies have almost the same distribution and can not be correlated with defect size.

RMS and Peak frequency

Laser interferometer
Rotating shaft

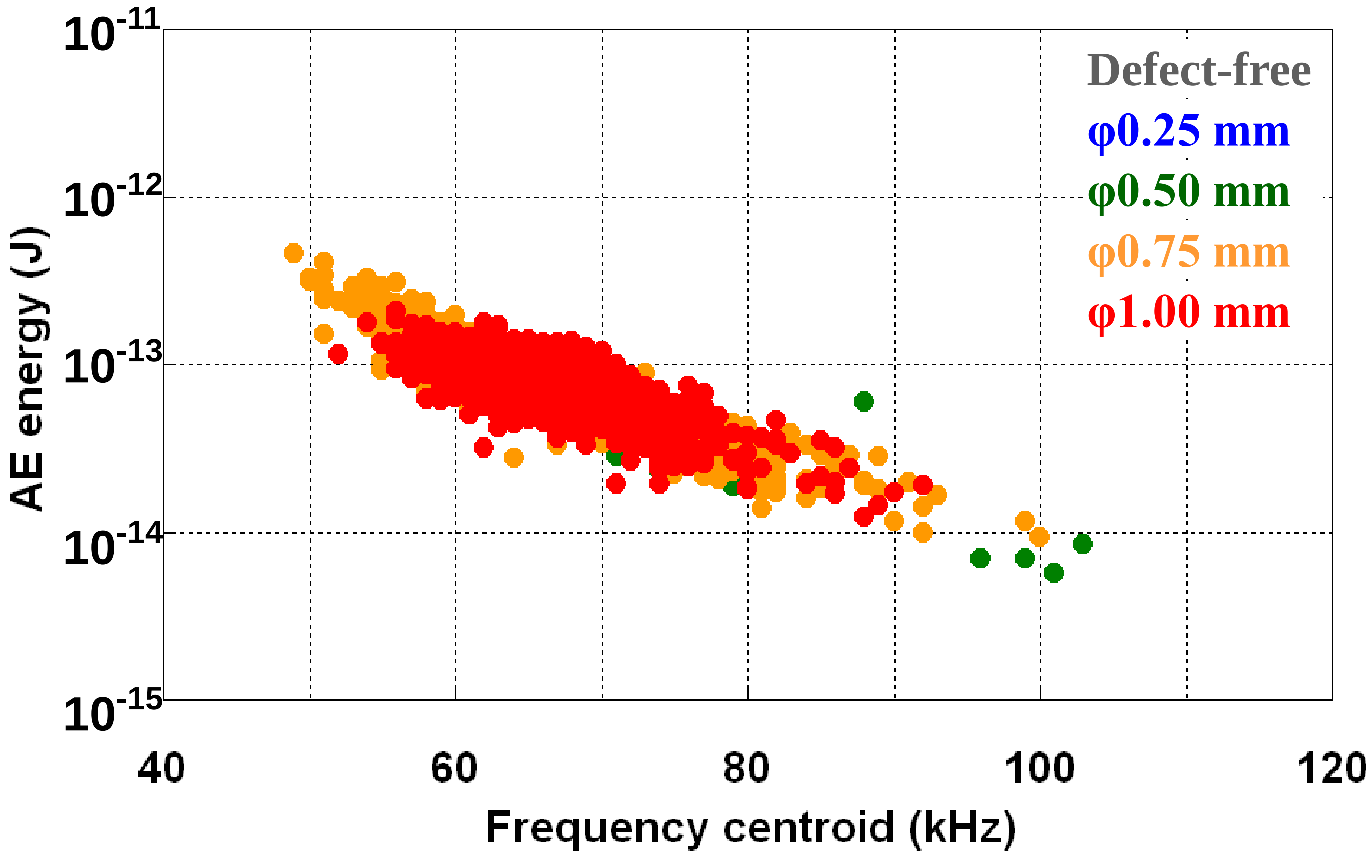


✓For defect sizes between 0.50 mm and 1.00mm, the maximum RMS voltage and peak frequency increases with defect size.

✓The RMS voltage and peak frequency can be used to detect defects larger than 0.50 mm.

Distribution of absolute AE energy and Frequency centroid

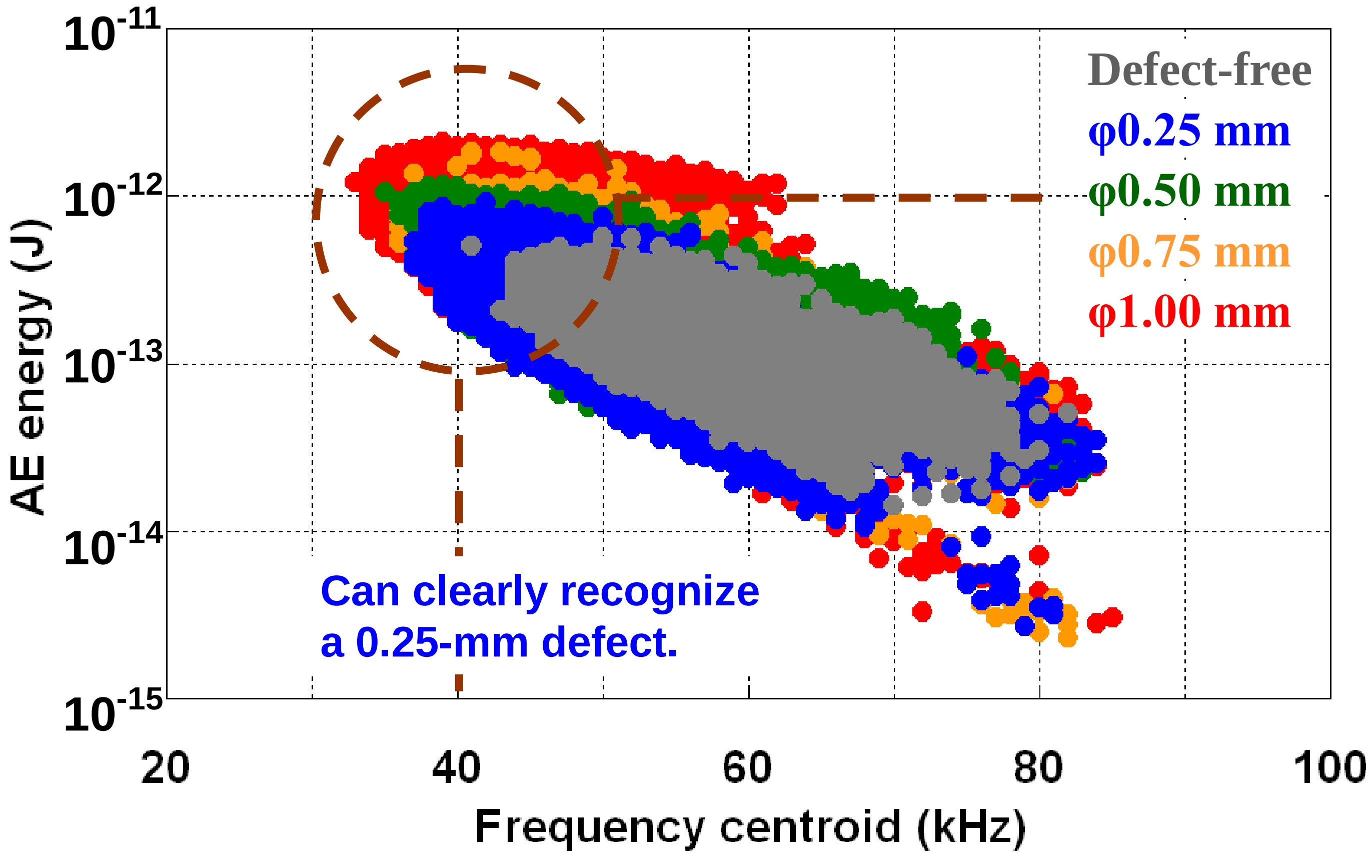
Piezoelectric sensor
Bearing housing



The correlation between the distributions and defect sizes is weak because there are few AE hits for defects smaller than 0.50 mm, and piezoelectric AE sensors have a non-flat frequency response.

Distribution of absolute AE energy and Frequency centroid

Laser interferometer
Rotating shaft



✓**With an increase in defect size, the frequency centroid tends to broaden, particularly at lower frequency, and the AE energy reaches higher values.**

Summary

- ✓ **We demonstrated that the non-contact AE measurement method using a laser interferometer can detect AE waves on a rotating shaft in a laboratory test.**
- ✓ **After analyzing various AE parameters, we observed that the frequency centroid and absolute AE energy carry the higher correlation with defects size on the rolling bearing.**
- ✓ **The distribution of frequency centroid and absolute AE energy obtained by shaft measurement can clearly detect smaller defects than bearing housing measurements using piezoelectric sensors.**
- ✓ **This method is therefore promising for condition monitoring on rotating machines in actual plants.**