IWC-HTS, Karlsruhe, 2017-9-14 15：15-15:30, Session6, OR6-5

Attempt to Generate Uniform Magnetic Field by Face-to-Face Magnet System Containing HTS Bulk Magnets

Tetsuo Oka, Kazuya Higa, Shunta Tsunoda, Jun Ogawa, Satoshi Fukui, Takao Sato, Kazuya Yokoyama, and Takashi Nakamura

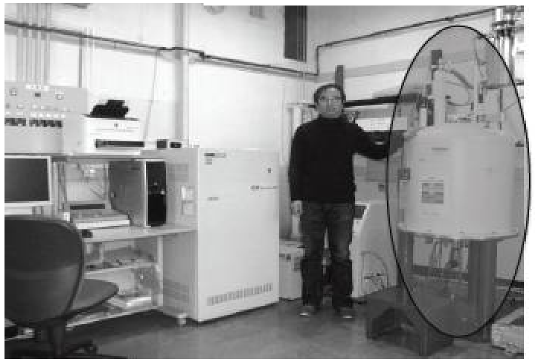
Niigata University, Ashikaga Institute of Technology, Riken,

Japan

Background

Needs for strong and compact static magnets

Concept of compact NMR device



Large-scale (270MHz, -6T)

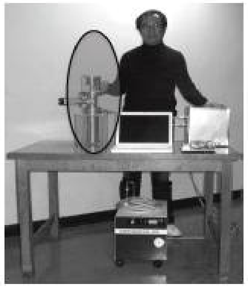


Table-top (200MHz, 4.7T)

T. Nakamura et al.

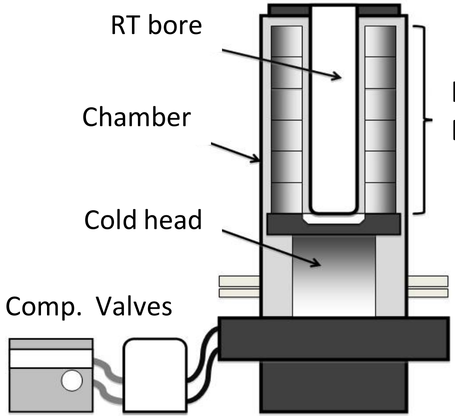


Illustration of hollow-type bulk magnet

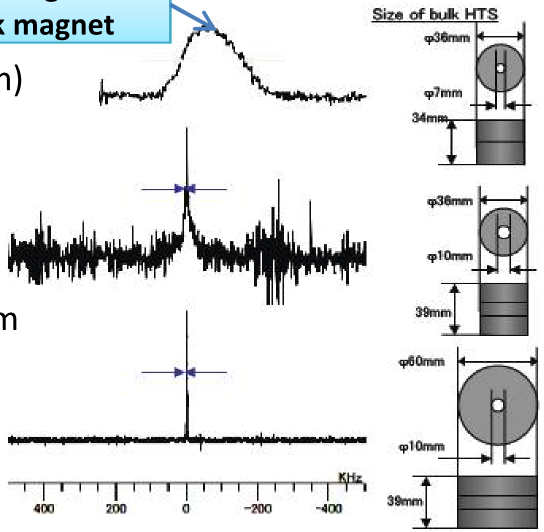
World-first NMR signal detected by bulk magnet

178kHz (1445ppm)

2.93kHz(23.2ppm)

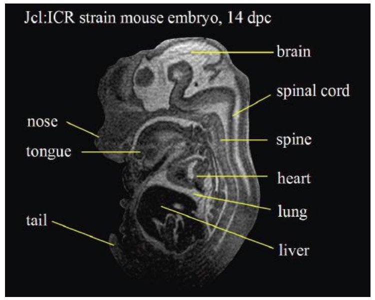
Improved to 5ppm

0.61kHz(4.85ppm)



Sample
Si - Rubber

NMR Imaging of baby mouse (2011)

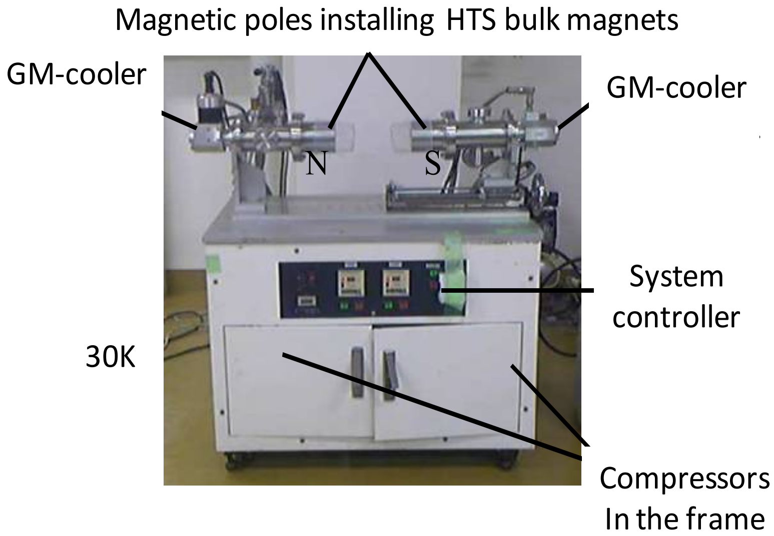


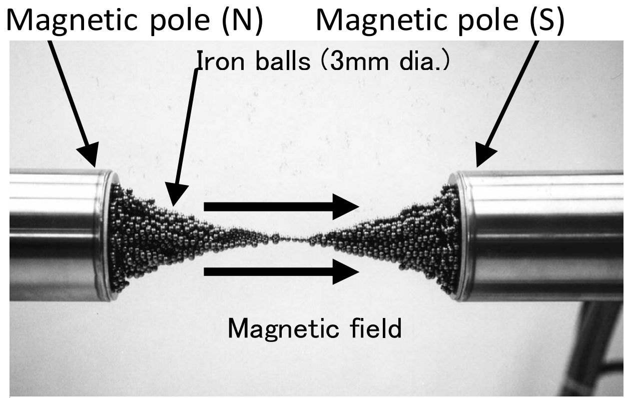
Magnetic uniformity was estimated to be feasible for application to compact NMR system

Nakamura T., et al., Concepts in Magnetic Resonance Part B (Magnetic Resonance Engineering) Vol. 31B(2) (2007), 5 Apr., pp. 65-70.

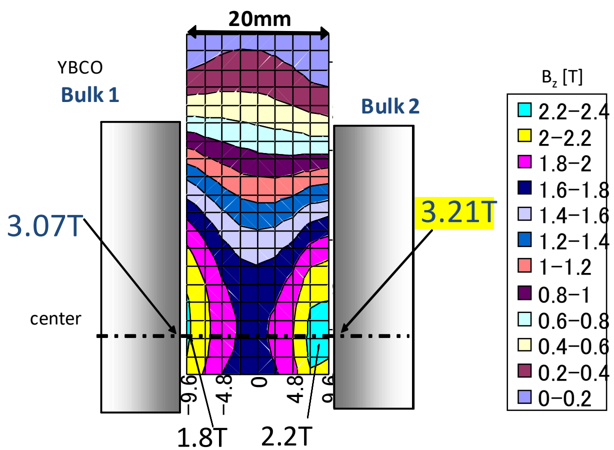
Ogawa K., et al., Applied Physics Letters 98, 2011, 234101-1–234101-3.

Bulk Magnets System



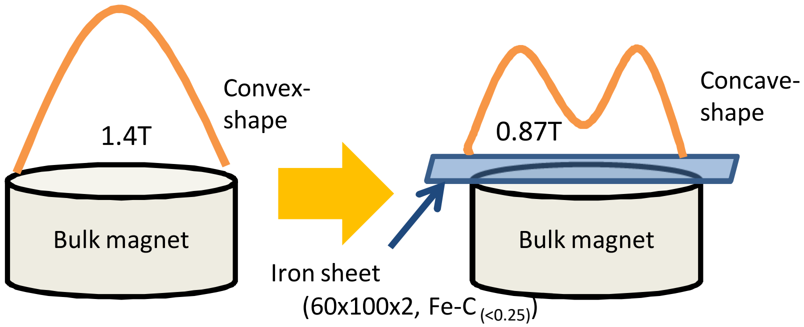


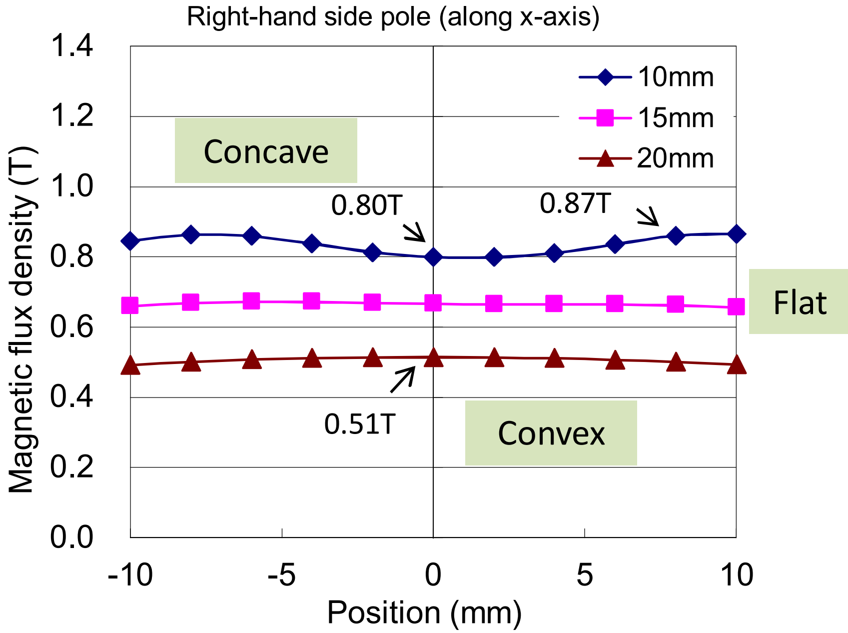
- Conical field distribution
- Maximum field at the center of the pole surface
- Steep field gradient



- Bulk magnets have the most intense field at the center of pole surface, which reflects the shape of the iron balls attracted to the magnets
- We attempted to obtain various magnetic field distributions for the industrial applications requiring uniform fields, like NMR/MRI and others

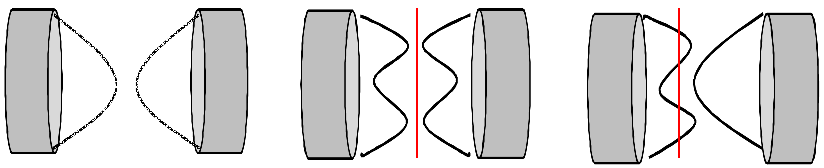
Deformation of Trapped Field Distribution



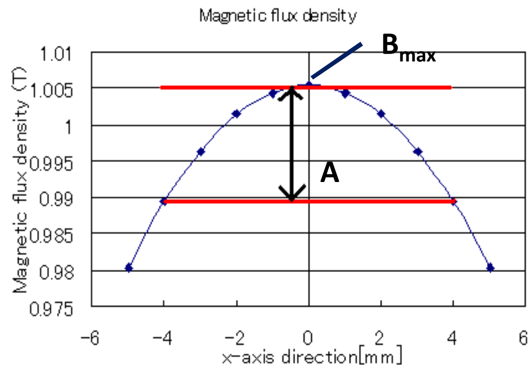


- In order to make the distribution smooth, we attached an iron plate on the pole surface generating 1.4 T
- The magnetic field distribution changed to concave by the shielding effect of iron plate, which changed from concave to convex with increasing distance
- This inferred the presence of flat region in the space

- We tried to estimate three type of arrangements of magnetic poles

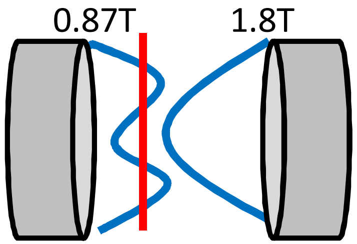


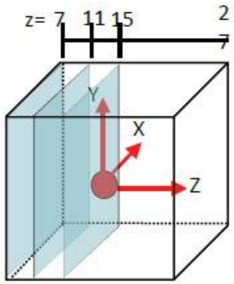
Pattern (a) Pattern (b) Pattern (c)



$$U = \frac{A}{B_{max}} \times 10^6 \quad \text{(ppm)}$$

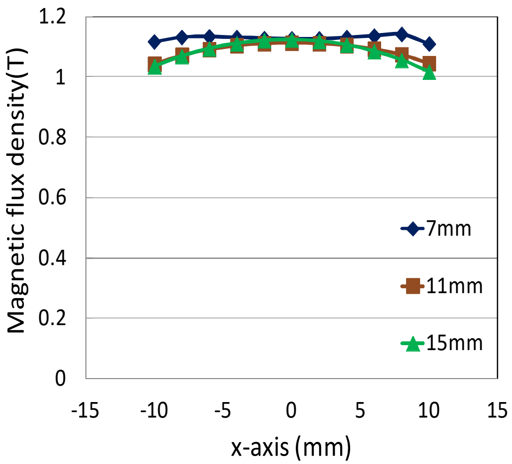
Combination of Concave and Convex



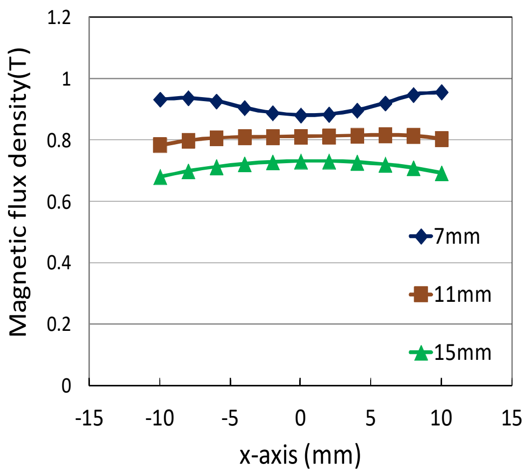


- The concave and convex-shape were combined with various gaps of 30-70 mm
- The concave shape gradually changed to be convex with increasing distance
- The flat lines appear at 11 mm distant from the surface
- At 30 mm gap, the magnetic field data remain the same value without lowering the field strength of 1.1 T with increasing distance

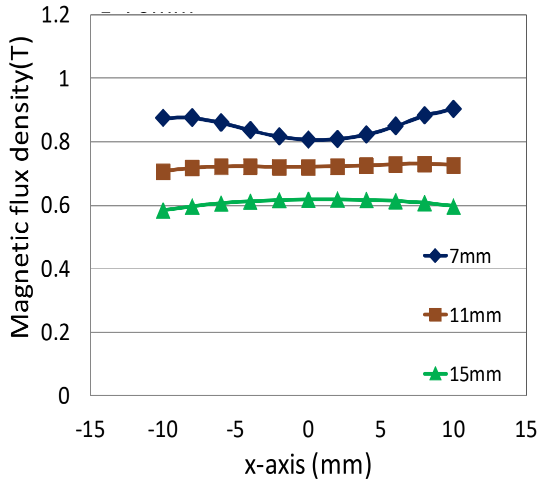
L=30 mm



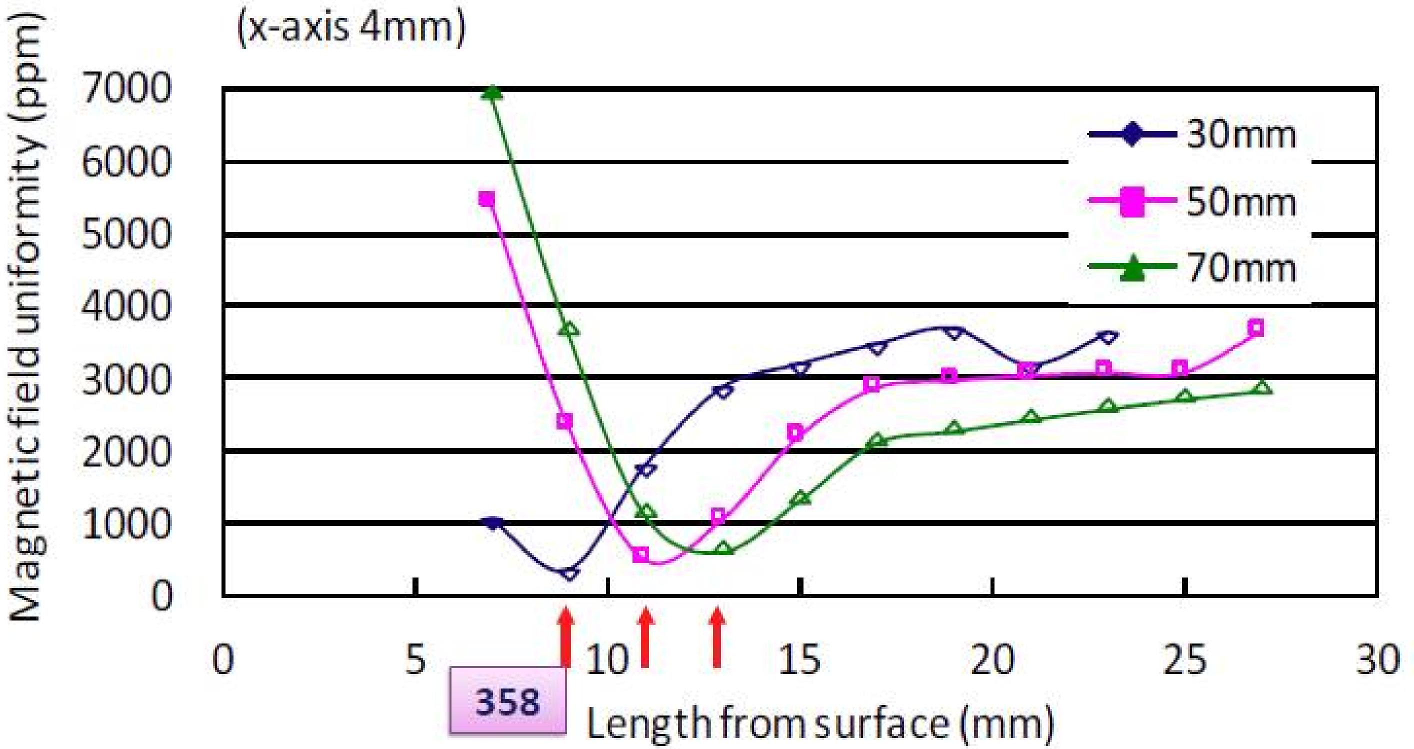
L=50 mm



L=70 mm



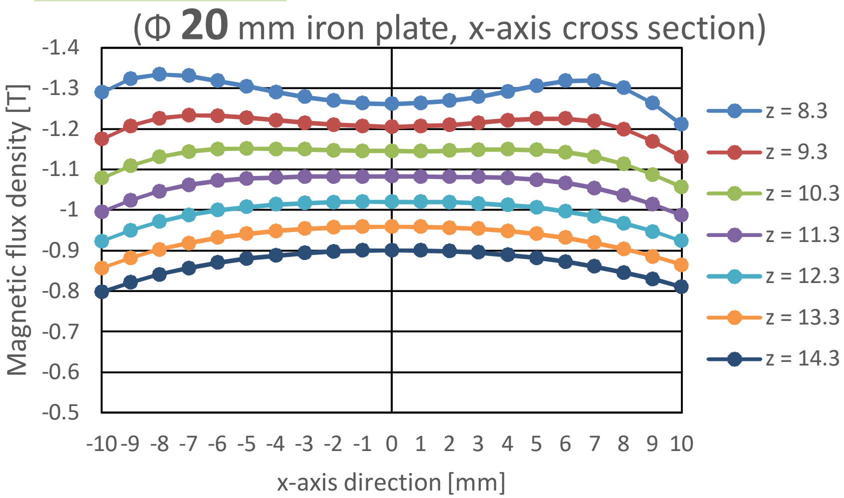
Estimation of Field Uniformity

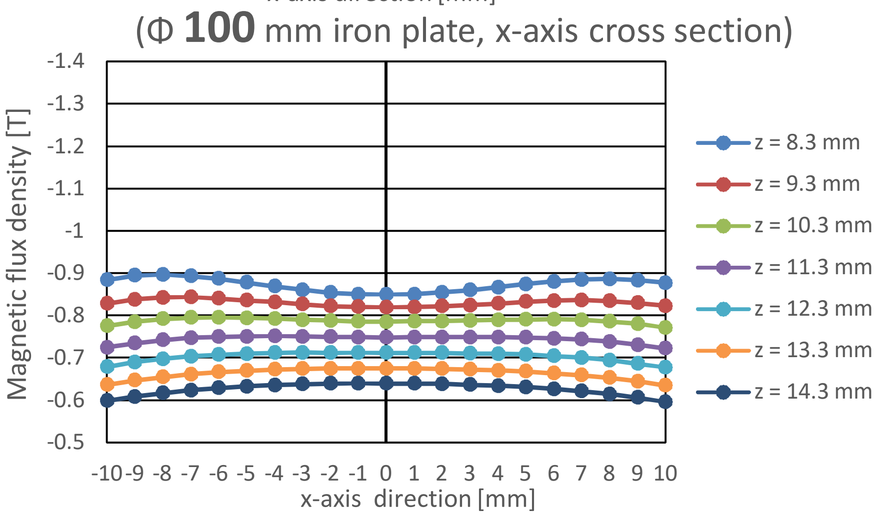


- We observed the most uniform point in each valley of profiles
- The most uniform distribution of 358 ppm was obtained at 9 mm position in 30 mm gap

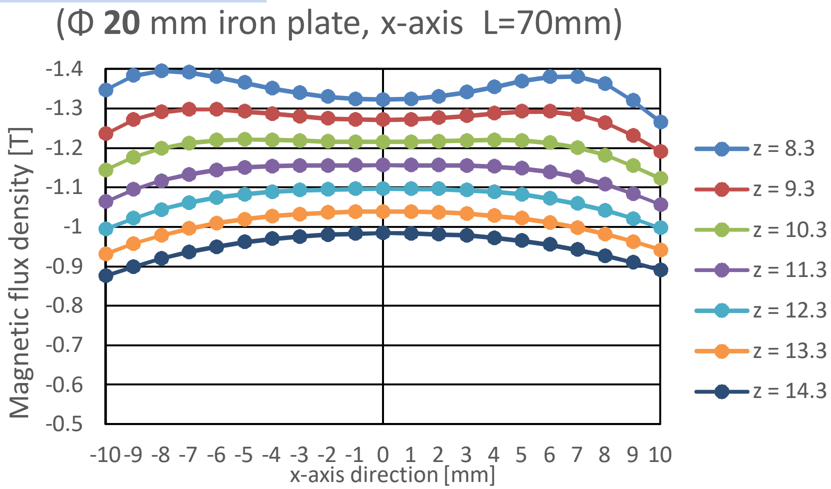
Field Distributions with Various Iron plates

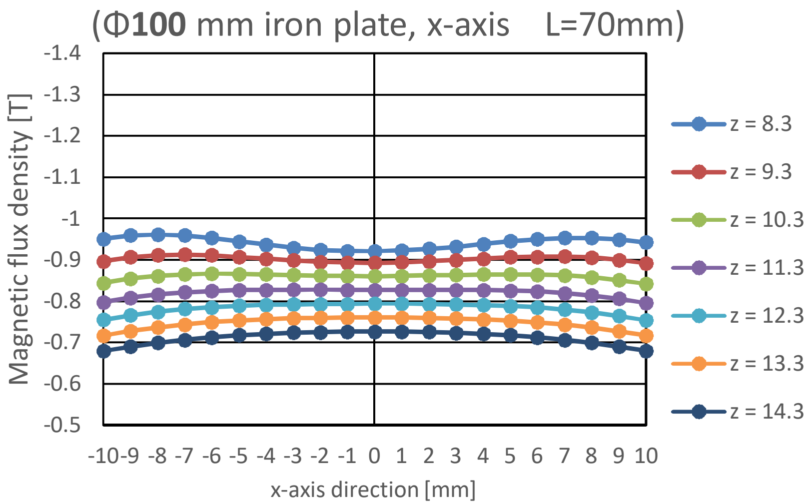
Single pole





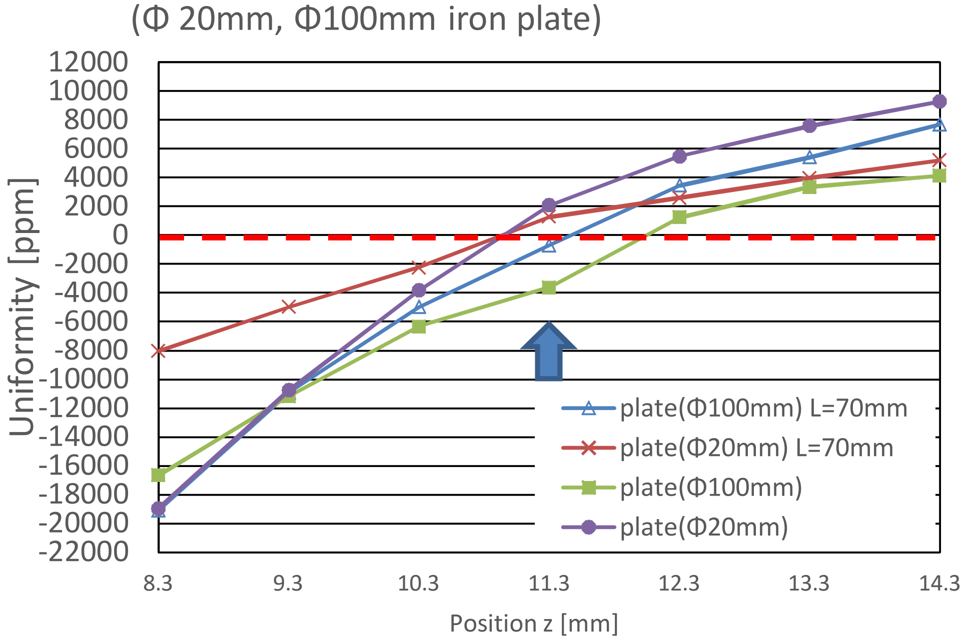
Face-to-face





- The field distributions and uniformity changes are capable of being adjusted by attaching the iron plates with various shapes and thickness

Changes of Magnetic Field Uniformity



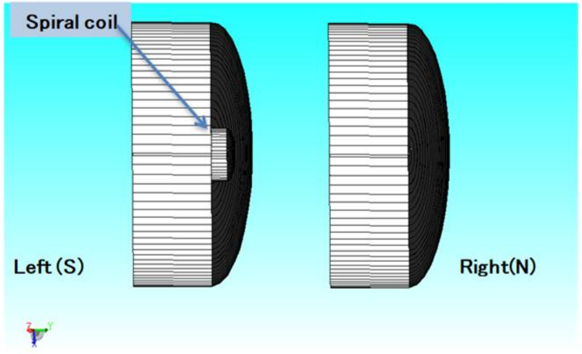
- The uniformity data go across the abscissa at about 11 mm distant from the pole surface
- This means that the possibly exist the uniform field regions
- The most uniform distribution reached 700 ppm at 11 mm position

		8.3	9.3	10.3	11.3	12.3	13.3	14.3
Face-to-face	plate(Φ100mm) L=70mm	-19088	-10919	-4987	-701	3451	5404	7690
	plate(Φ20mm) L=70mm	-8030	-4980	-2247	1264	2578	3953	5179
Single	plate(Φ100mm)	-16661	-11189	-6341	-3637	1223	3330	4129
	plate(Φ20mm)	-18949	-10757	-3827	2073	5467	7586	9276

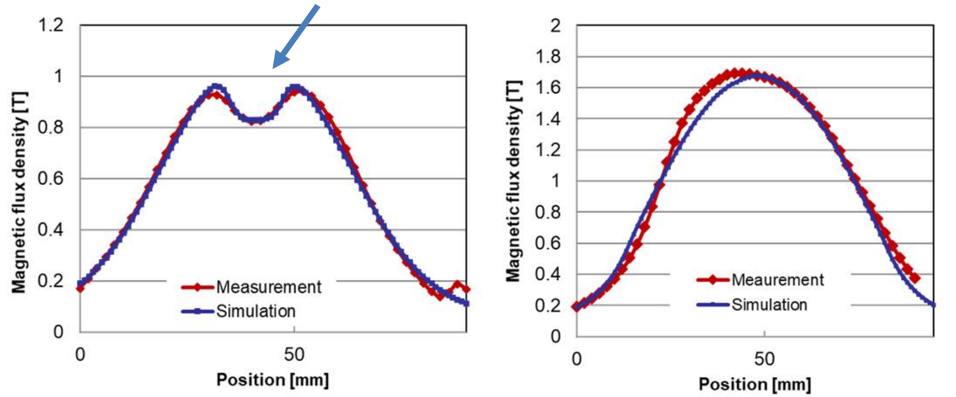
Data were estimated in the range of 4 mm along x axis

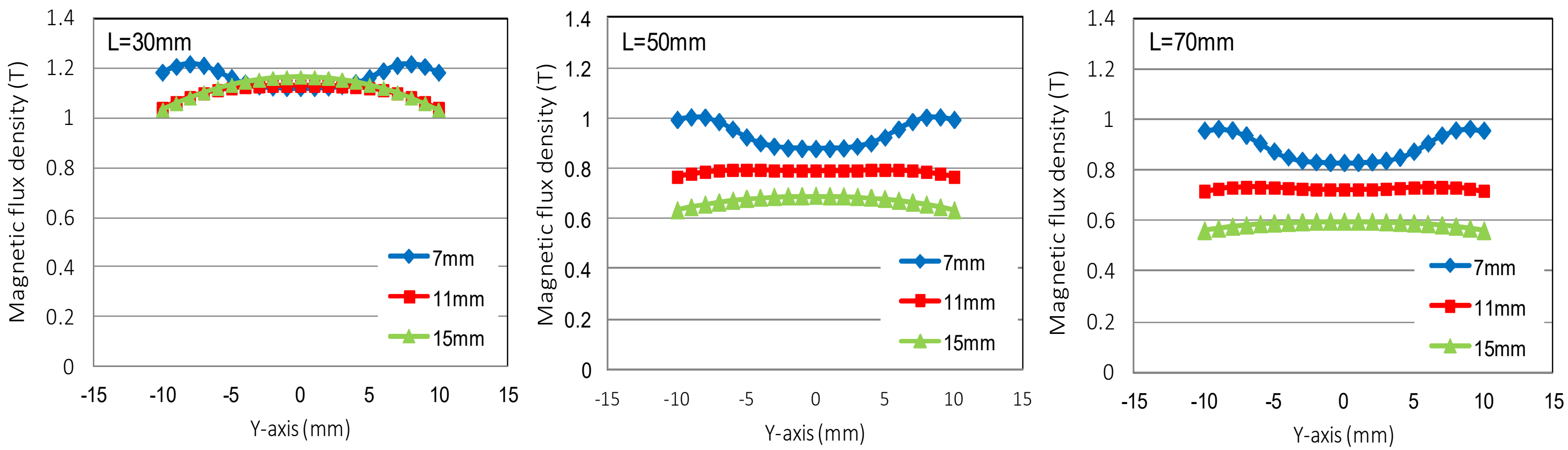
Numerical Simulation

A small spiral coil was attached on the centre of the pole surface



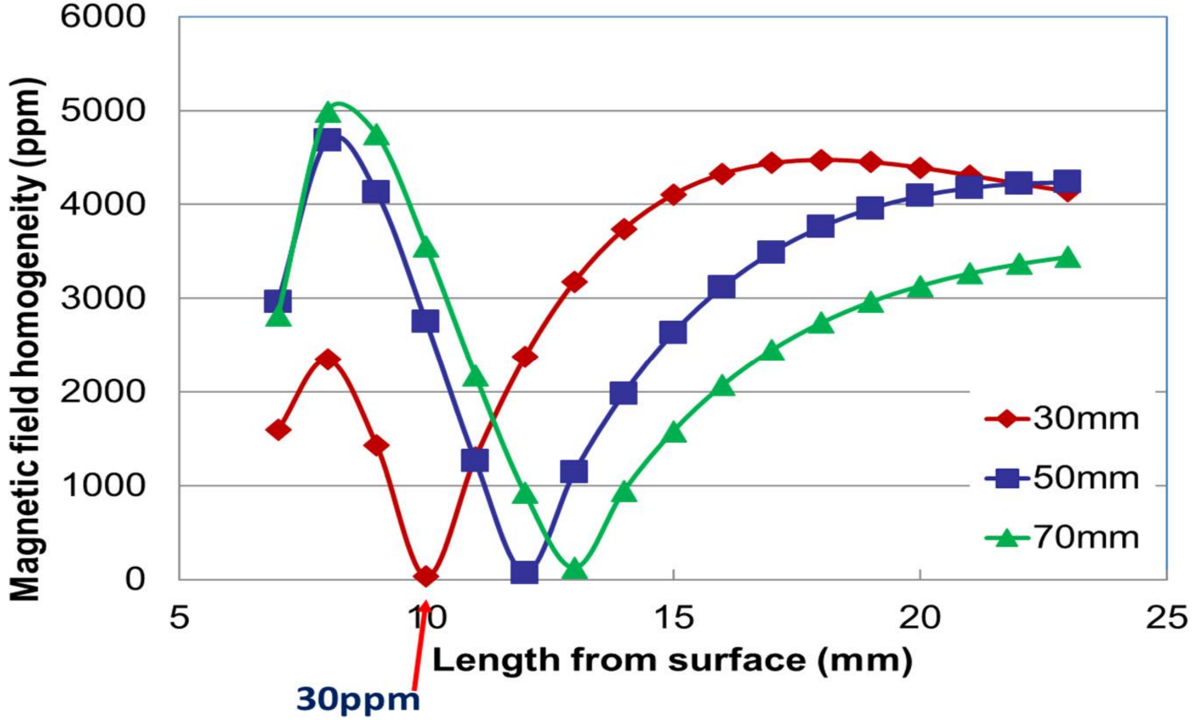
The concave field shape was obtained





- The simulation results reproduce the concave profiles as same as shown in the experimental
- The field distributions change from concave to convex shapes with increasing distance as well
- The distribution profile at 30 mm gap keeps their field strength at 1.1 T with changing positions

Performance of Uniformity
(Numerical simulation)



- The simulated uniformity shows the similar profiles to those of measurement
- We can observe the uniform points in each valley of the profiles
- The best uniformity was obtained as 30 ppm at 10 mm distant from the pole surface in the gap of 30 mm
- This implies the feasible applications of uniform field to practical industries

Conclusion

- We succeeded in obtaining the uniform magnetic field in order to detect NMR signals for possible industrial applications to the compact NMR/MRI devises
- The data in the experimental measurements and the numerical simulations exhibited the similar profiles in various gaps
- The flat regions of magnetic flux density must exist in the valleys in the range from 9 to 13 mm distant from the pole surface
- The data of uniformity have reached 358 ppm and 30 ppm at 1.1 T by the experimental and simulation processes, respectively
- The performances are estimated to be sufficient to detect NMR signals in the gaps of the magnetic poles