



Induction Synchrotron and Proof of principle experiment in the KEK 12GeV-PS .

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KEK and Tokyo Inst. of Technology

1. Motivation

Intensity up-grade → Induction Synchrotron.

2. Superbunch Acceleration.

3. R&D works on the magnetic core material and the switching device.

4. Proto-type bench test.

5. Demonstration plan.

Summary.

Induction Synchrotron (I).

★ Intensity up-grade of the accelerator.

Neutron spallation source.
Accelerator-driven nuclear waste transmutation.
Neutrino oscillation experiment.
Muon physics.

★ High intensity beam causes,

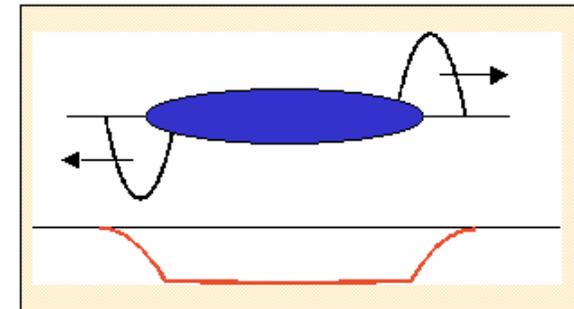
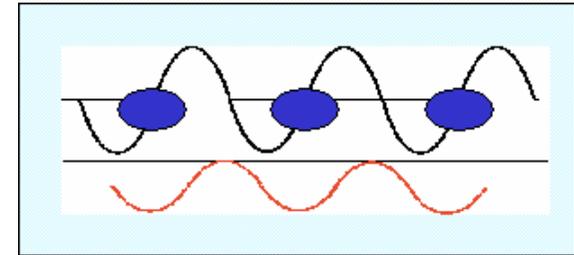
Strong space-charge effect
large tune shift.
space-charge induced resonance.

➡ Restrict the charge density in the RF bucket.

★ Need more room for more charge.

Vacancy between bunch-bunch in the RF accelerator is still an apartment for more habitants!!

It is exactly the **Barrier-bucket !!**



?? How do we accelerate the bunch keeping long??



Induction Synchrotron (II).

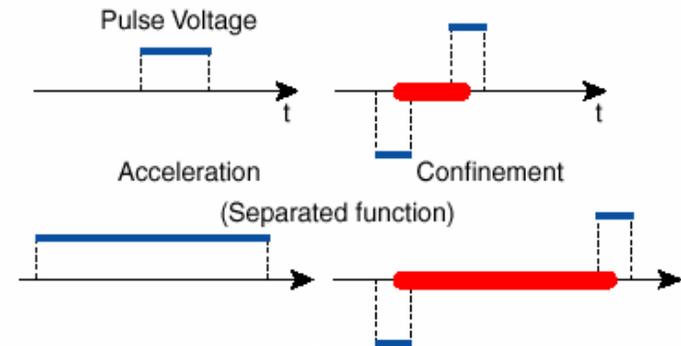
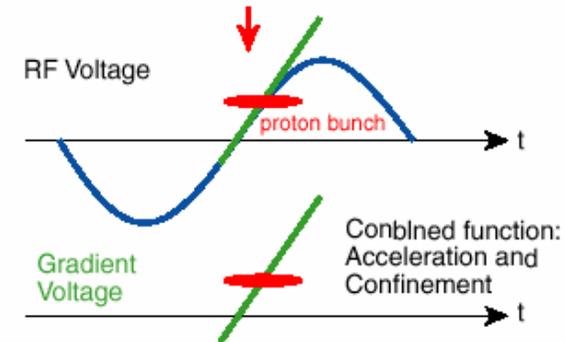
We already have a pulse devices for a long pulse.



Longitudinal confinement and acceleration are independently achieved by the separated induction cells.

Longitudinally Separated Function Accelerator

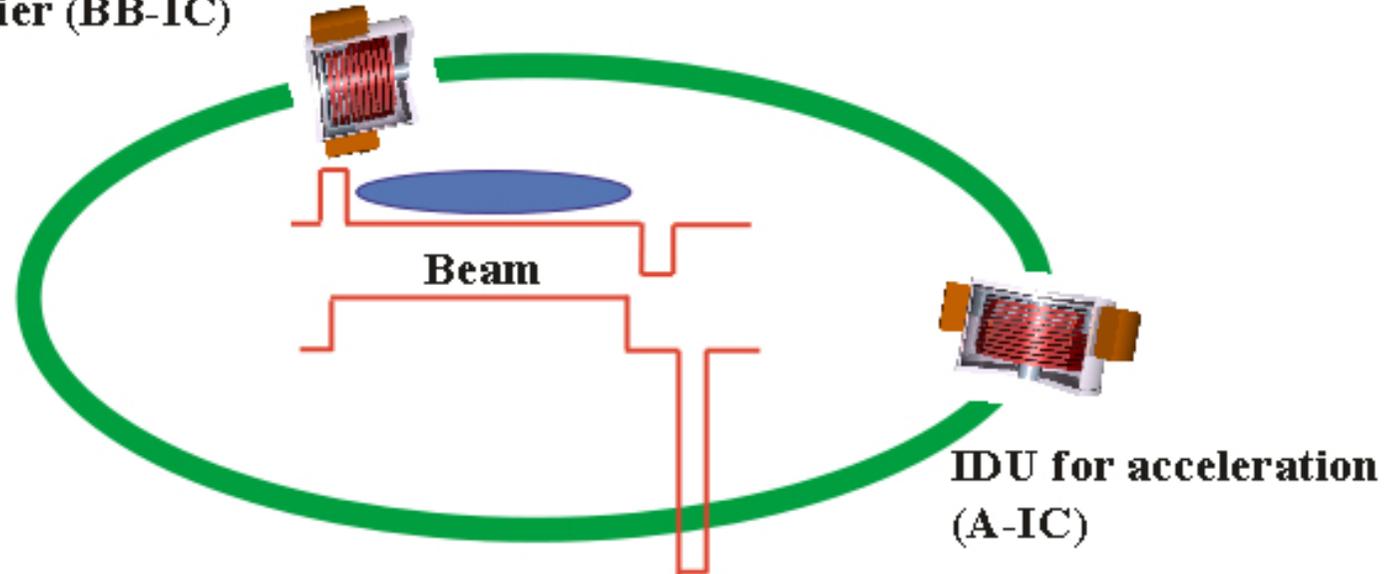
RF Synchrotron



Induction Synchrotron

Superbunch acceleration. --Induction cell arrangement--

IDU for barrier (BB-IC)



For Barrie bucket

Pulse width	:	50 ~ 100ns
Voltage	:	140kV
Repetition rate	:	670 ~ 800kHz

For Acceleration

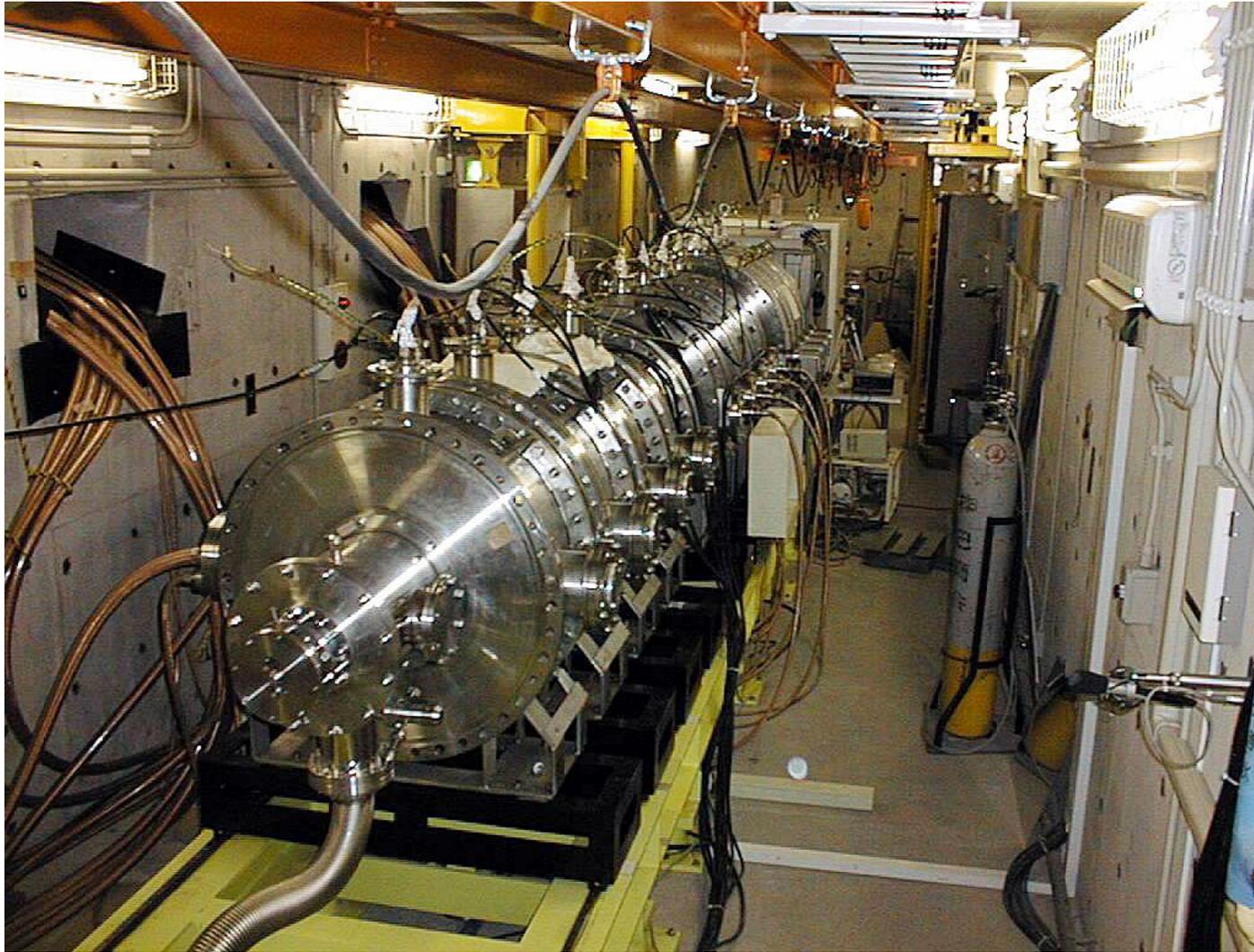
Pulse width	:	800 ~ 1200ns
Voltage	:	25kV
Repetition rate	:	670 ~ 800kHz

For KEK 12GeV PS.

Induction Synchrotron and a proof experiment in the KEK 12GeV-PS

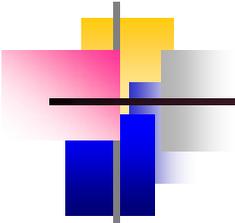
RPIA2002
Oct. 29, 2002@KEK

3.6MeV Induction LINAC at KEK-JAERI.



Induction Synchrotron and a proof experiment in the KEK 12GeV-PS

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R&D works.

- ✦ Magnetic loss.

 - Selection of a Magnetic material.

- ✦ Cooling system.

- ✦ Fast Switching device.

 - Switching speed,

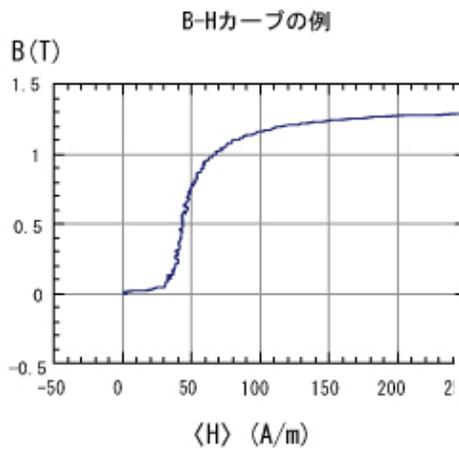
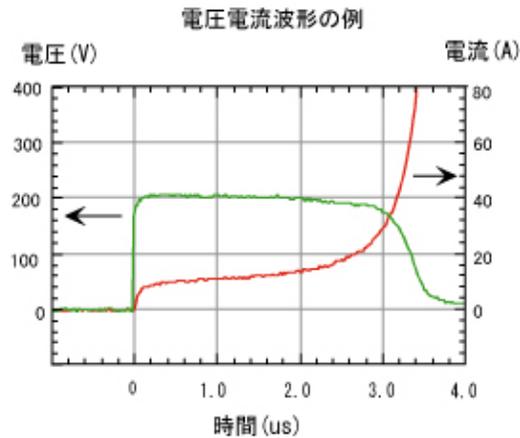
 - Turn On & Off performance,

 - On resistance.

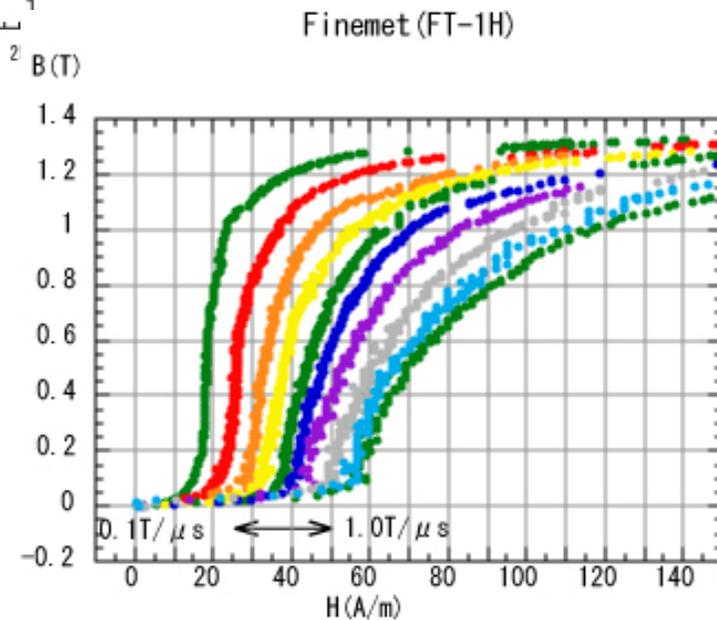
- ✦ Timing & Voltage Control.

Magnetic Characteristics measurement.

Finemet (FT-1H)

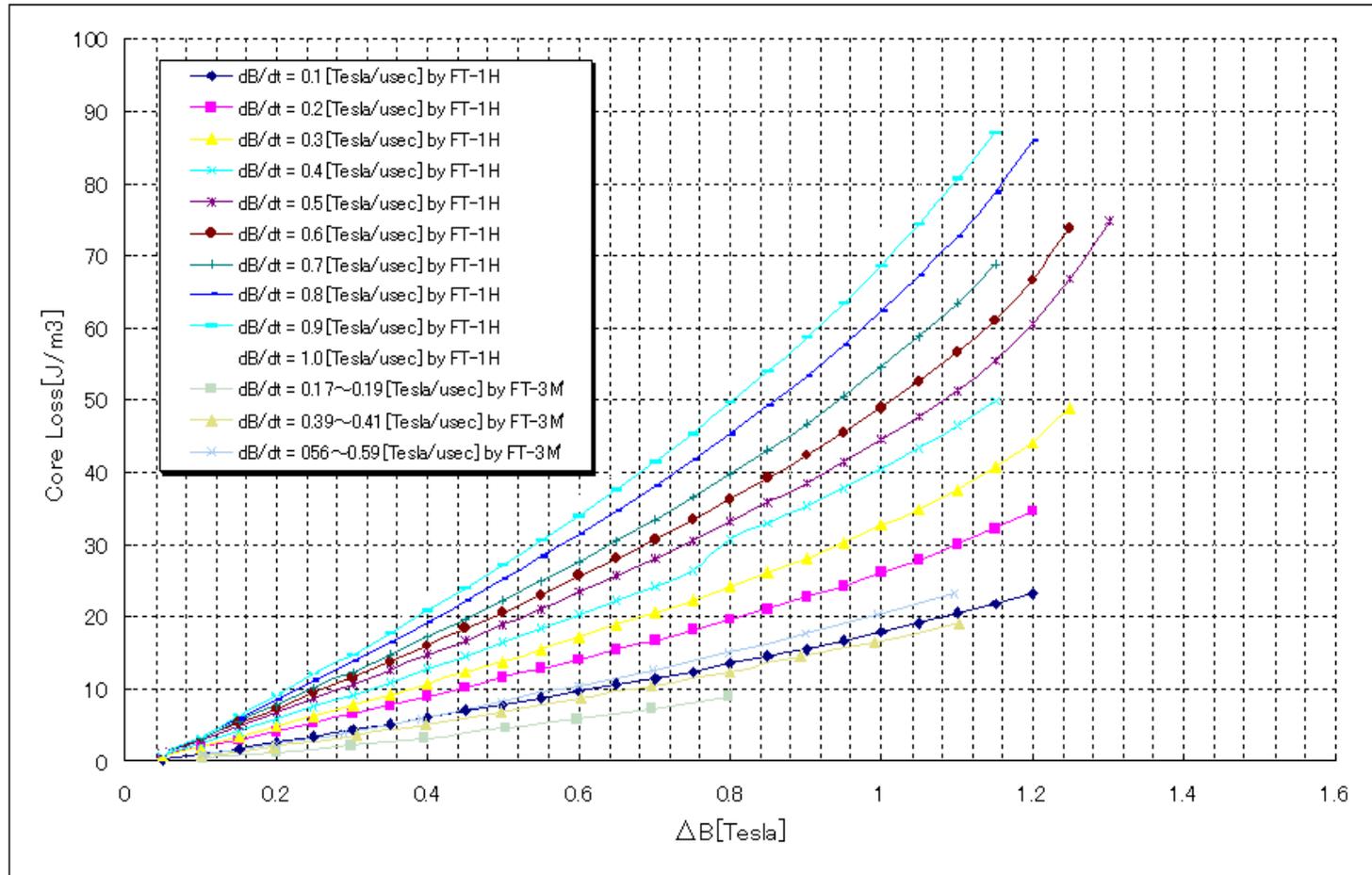


Exact measurements:
Magnetic material loss,
Rise time dependence,
Minor loop behavior,
Modeling.



Core loss vs. excitation rate.

Hitachi FINEMET core



Switching elements.

Requirements;

High voltage,

Large current,

Low loss → Low on resistance,

High speed, }
 } Low on resistance
 } Low capacitance.

FET: Field Effect Transistor

GTO: Gate Turn-On-thristor

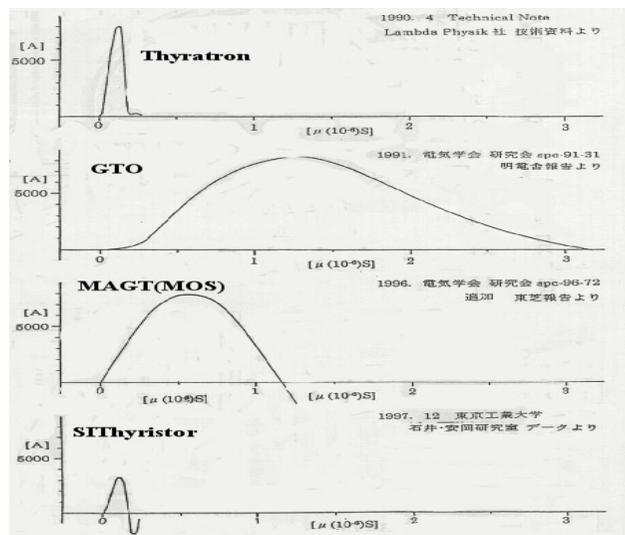
IGBT: Insulated Gate Bipolar Transistor

MAGT: MOS Assisted Gate-triggered Thyristor

SIT: Static Induction Thyristor

Cool MOS FET

SiC MOS FET



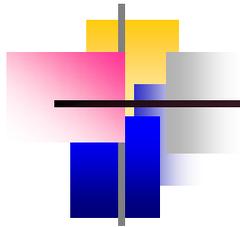
For the 1st R/D pulse modulator;

FET was chosen,

High repetition rate ← 1MHz

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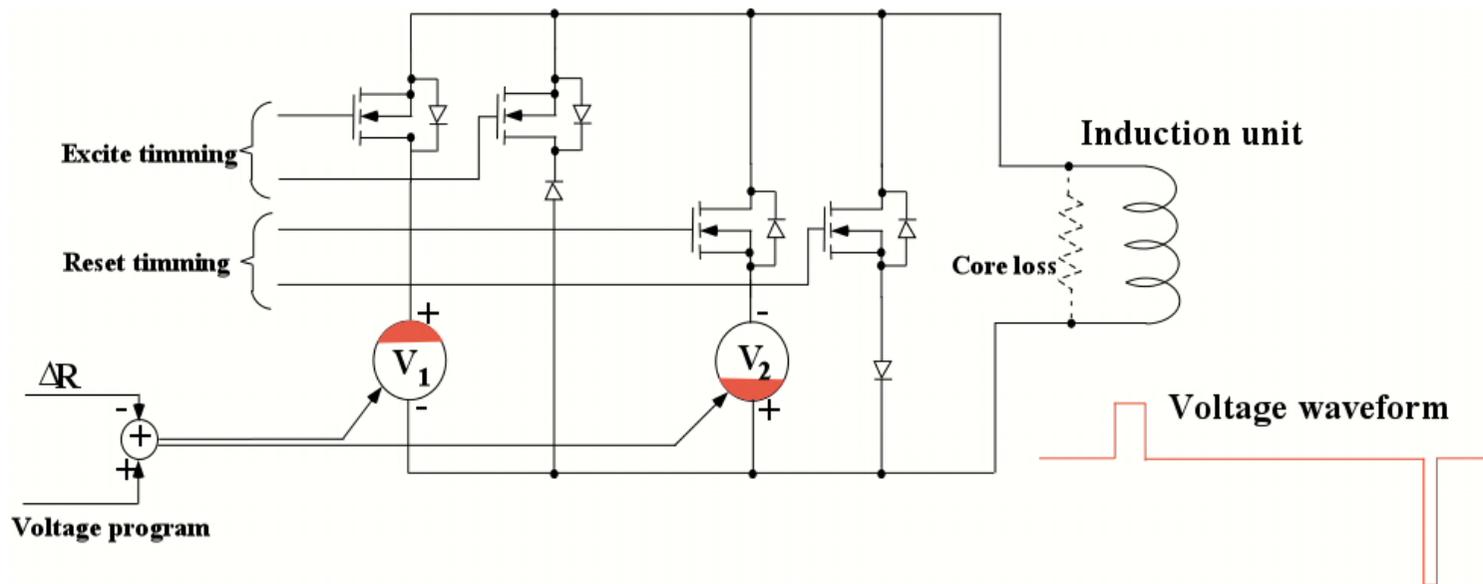


High speed pulse modulator.

FET modulator

Independent trigger for
excite,
magnetic reset.

Voltage feedback for
beam tracking,
phasing.

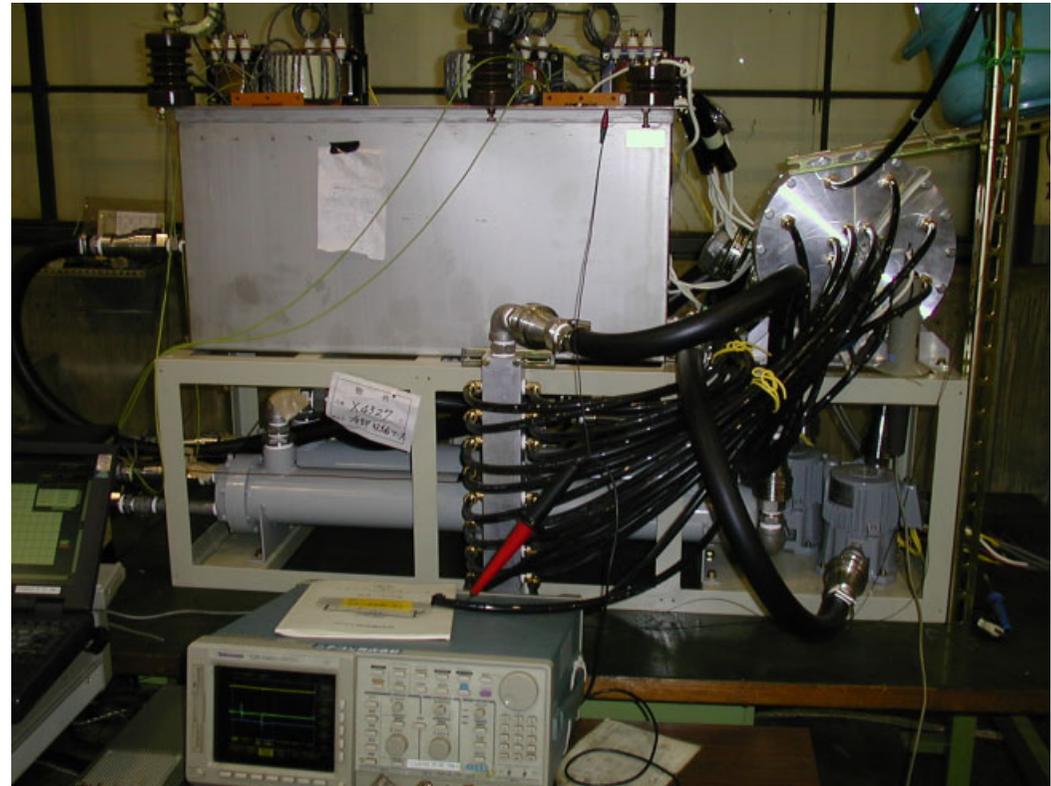
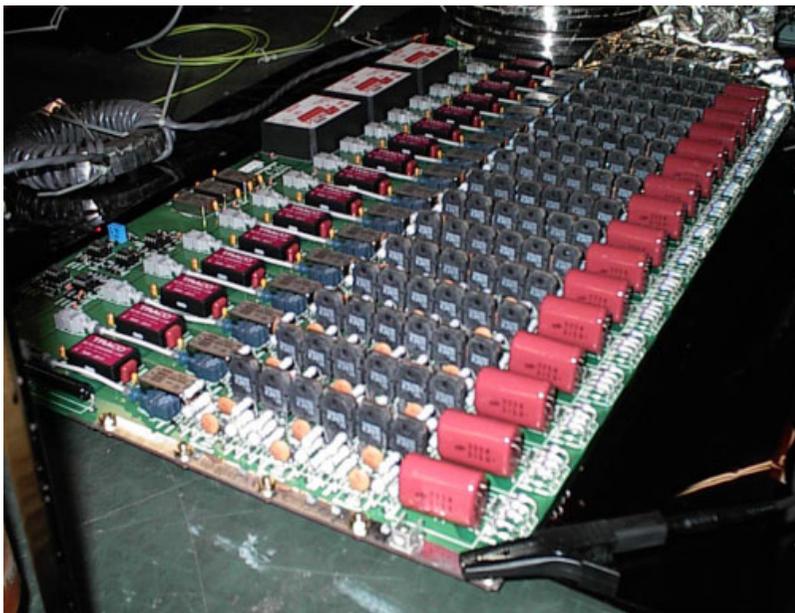


Modulator (First prototype).

Design target

5kV, 100A, **100kHz**

With set/reset operation.

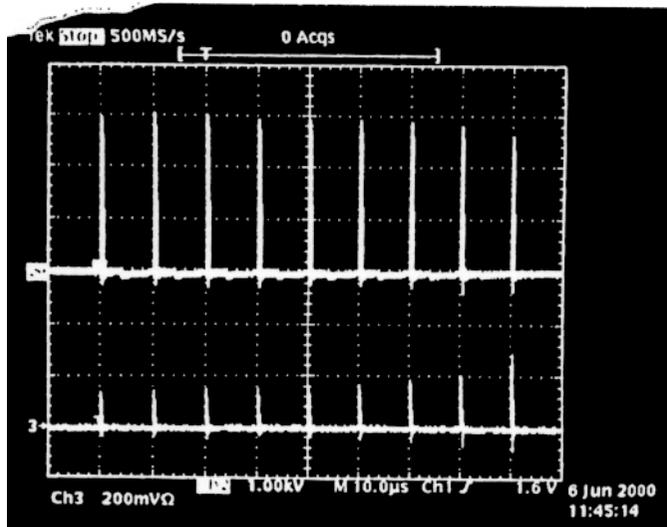


(FET 6-parallel x 16-series) x 4-boards,
Oil impregnated cooling system,
Voltage stabilization.

Induction Synchrotron and a proof experiment in the KEK 12GeV-PS

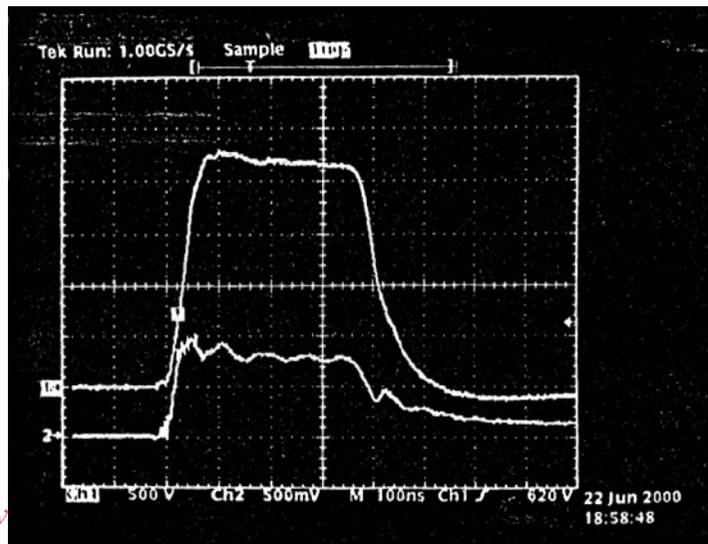
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First prototype Induction test.



We successfully achieved the operation of 3.8kV, 40A, 100kHz.

Some problems causing from
Noise,
Stray-capacity,
Cooling system, *etc.*

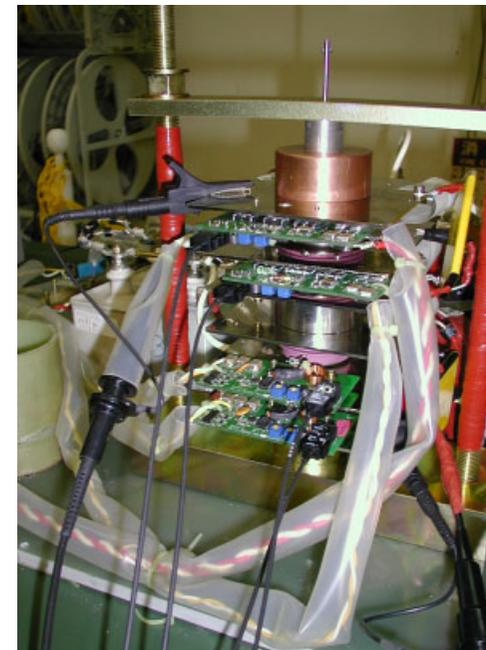
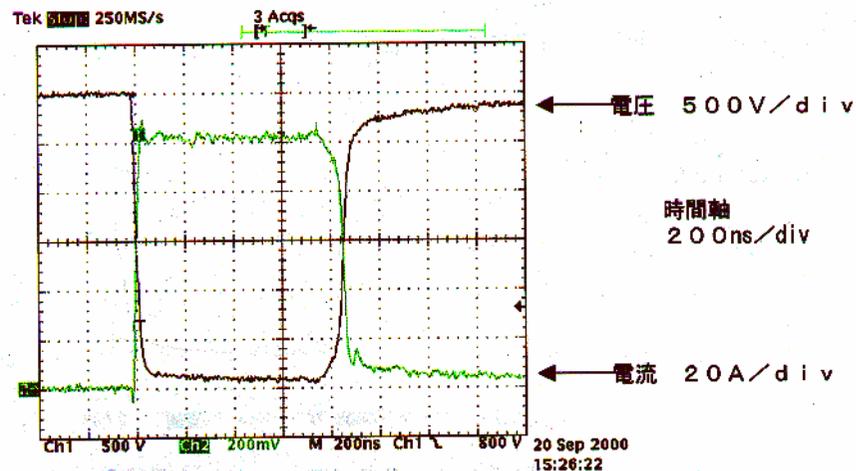


Modulator (Second prototype).

High speed switching test on Static Induction Thyristor(SIT).

Current Rise time $< 50\text{ns}$,
Fall timewill be $< 50\text{ns}$,
Current $\sim 200\text{A}$,
Voltage 4kV ,
Repetition rate $> 500\text{kHz}$ (examining).

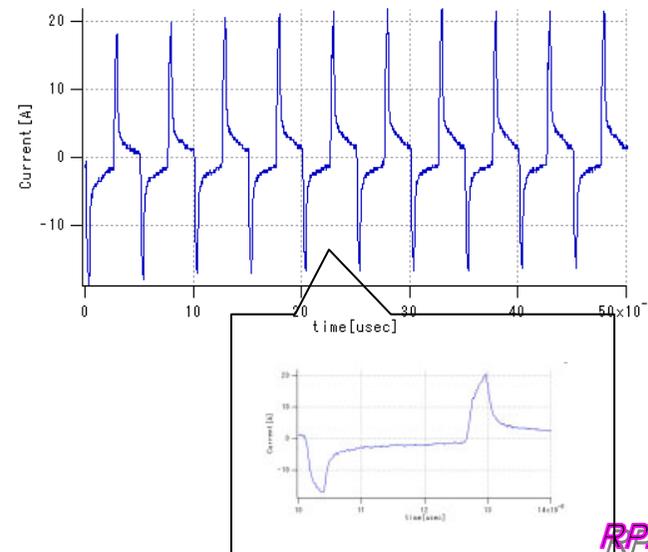
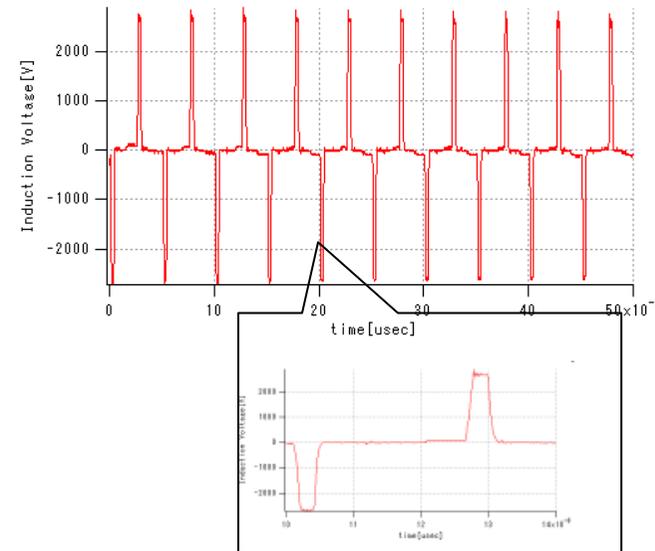
Advantages:
A single element,
Low output impedance,
Compact.



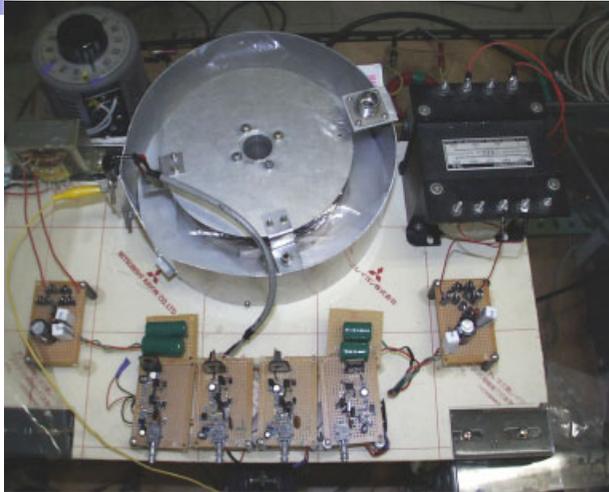
Second prototype Induction test.

SI-Thyristor modulator.

2.5kV, 200kHz operation
was successfully achieved.

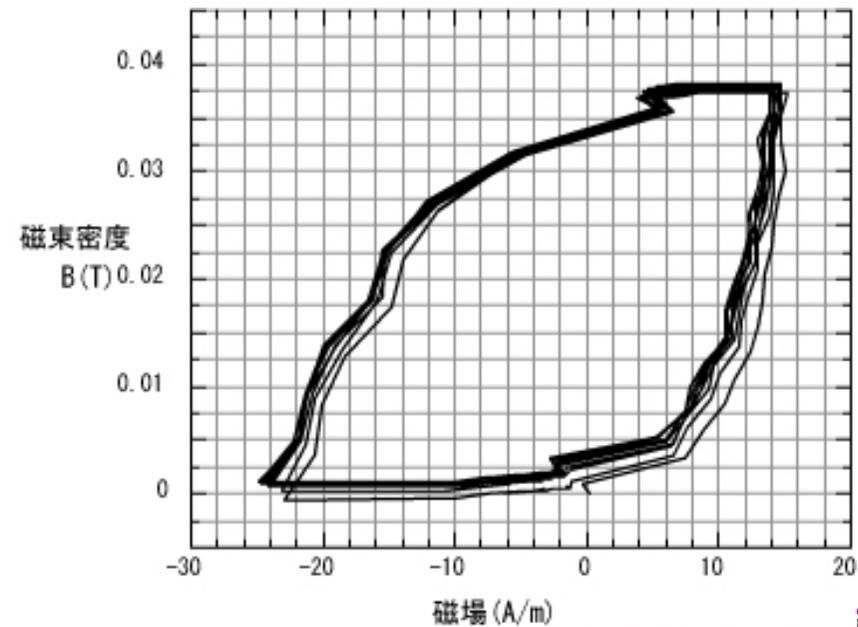
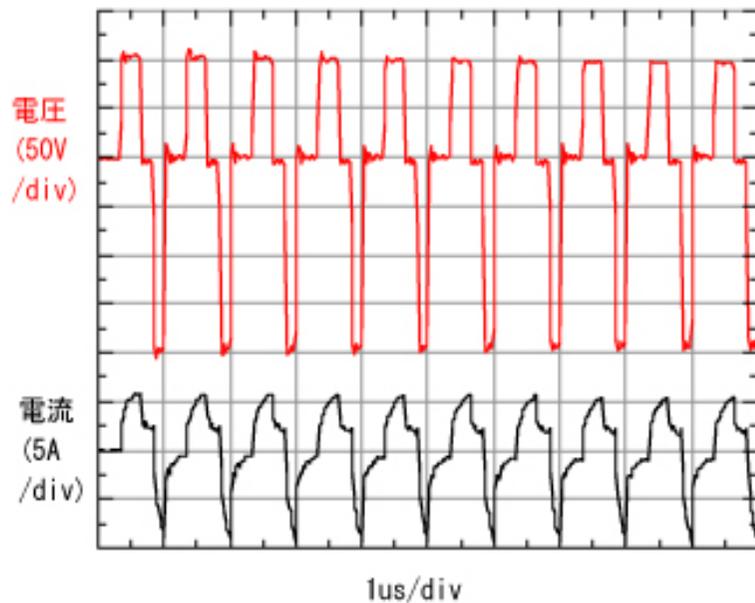


Small size performance test.



100V, 1MHz operation with set/reset.

Exact B-H loop tracking to *investigate the stability of the mag.-loop*.



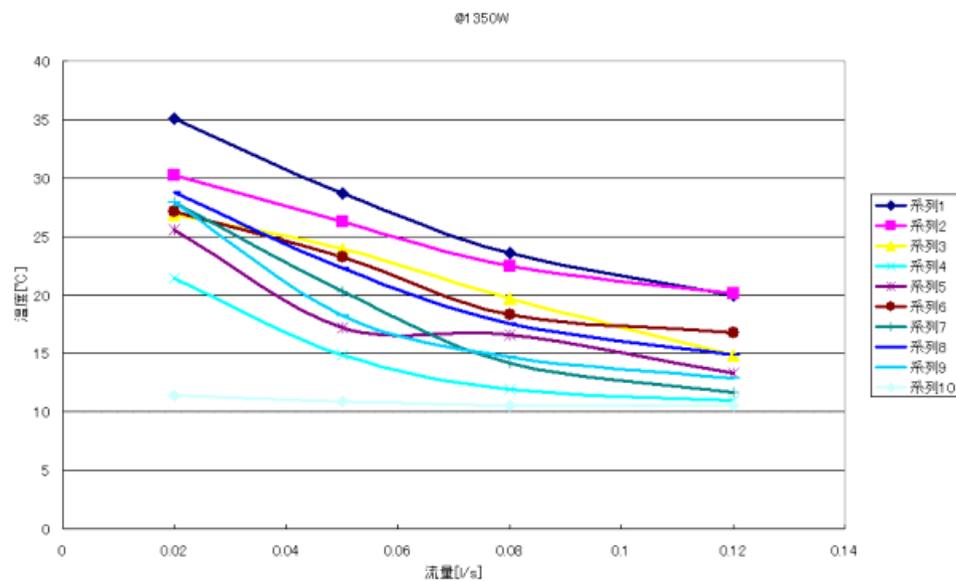
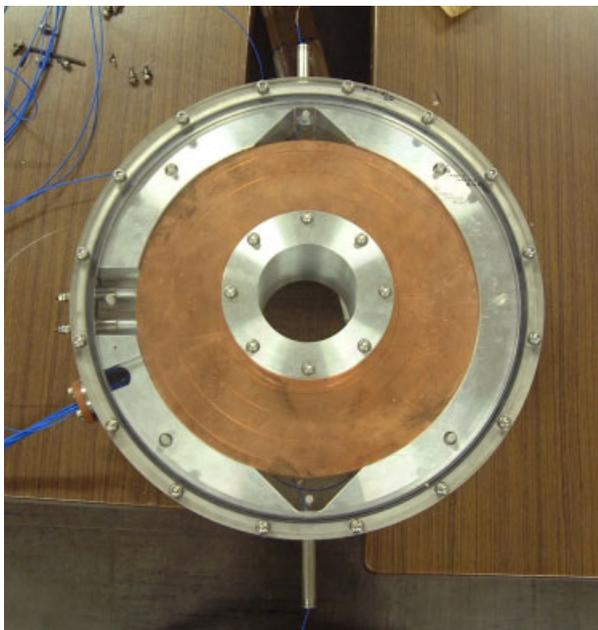
Cooling bench- test.

3kW heater impregnated disk.

Water cooling channel.

Water flow monitoring.

Temperature monitoring.



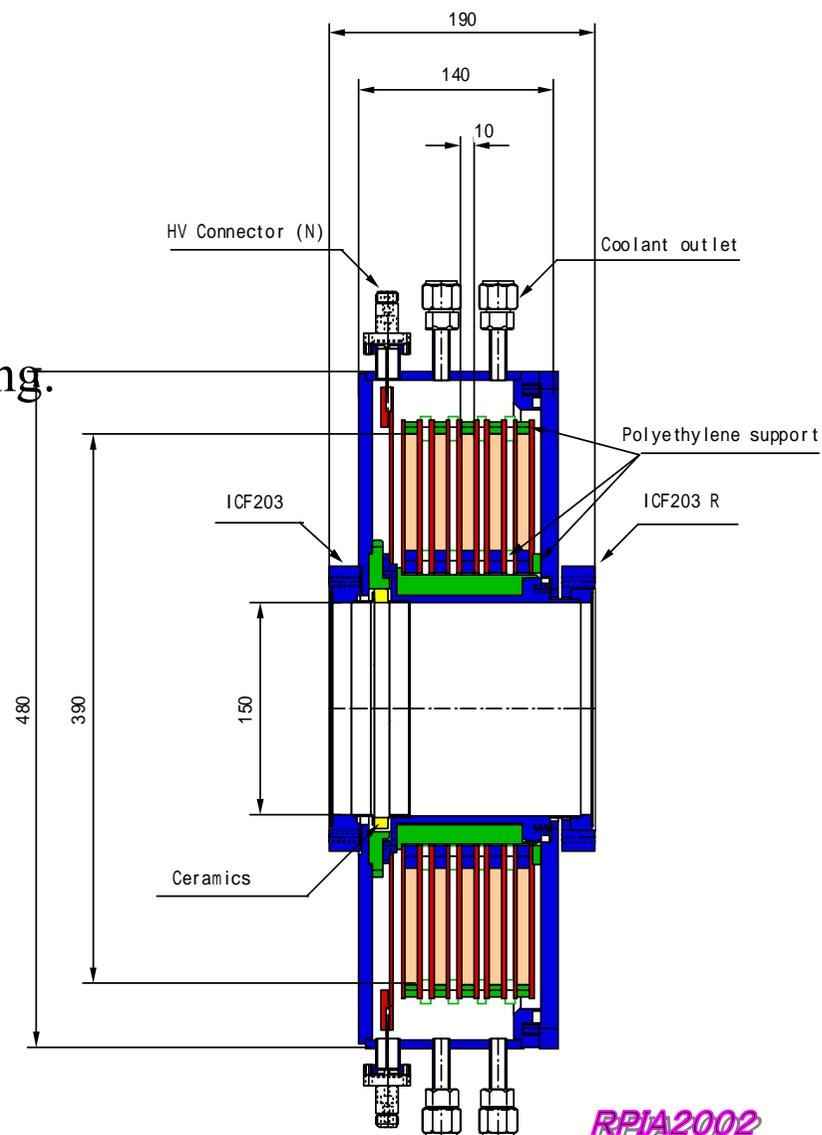
1MHz induction design.

2~2.5 kV, 1MHz induction unit,
1MHz 2.5kV 350ns modulator

have been assembled and
the test operation is now undergoing.

1MHz long-term test operation is
undergoing.

The unit will be installed in the KEK
12GeV PS by the end of March 2003.



Demonstration plan of the Superbunch acceleration

Step1: in KEK PS.

Three RF buckets are stacked.

Accelerate by the induction voltage, keeping the bunch by the conventional RF bucket (because of the financial problem).

Step2:

Five RF buckets are stacked.

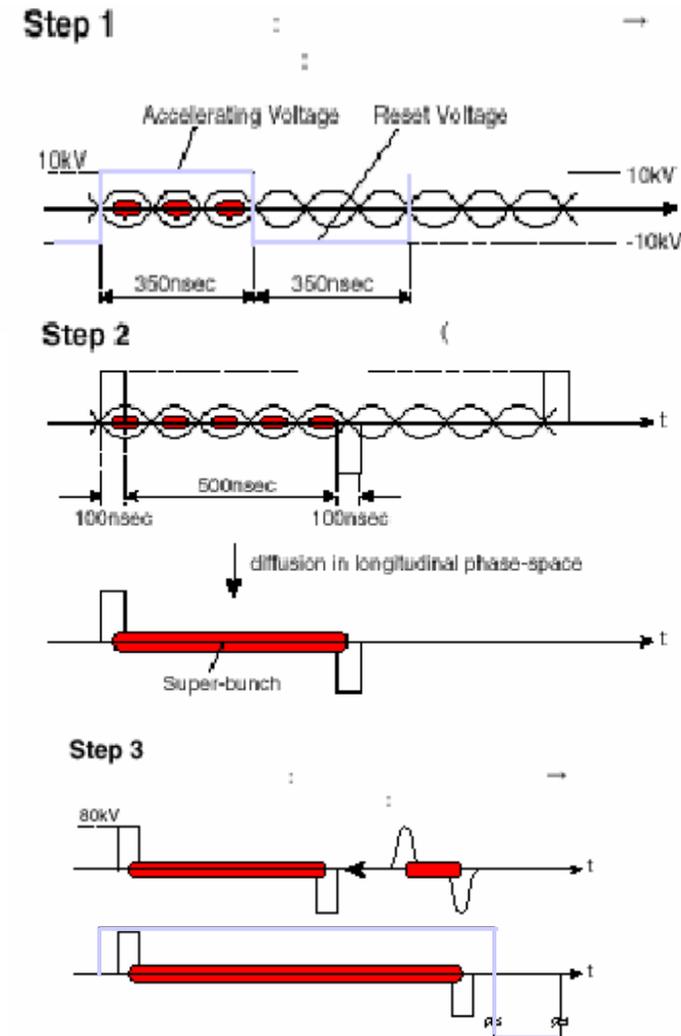
Stacking is changed from the RF to barrier by the short pulse induction unit.

Accelerate by the long pulse induction unit.

Step3:

The injected bunch is merged by a pulse diagnostics.

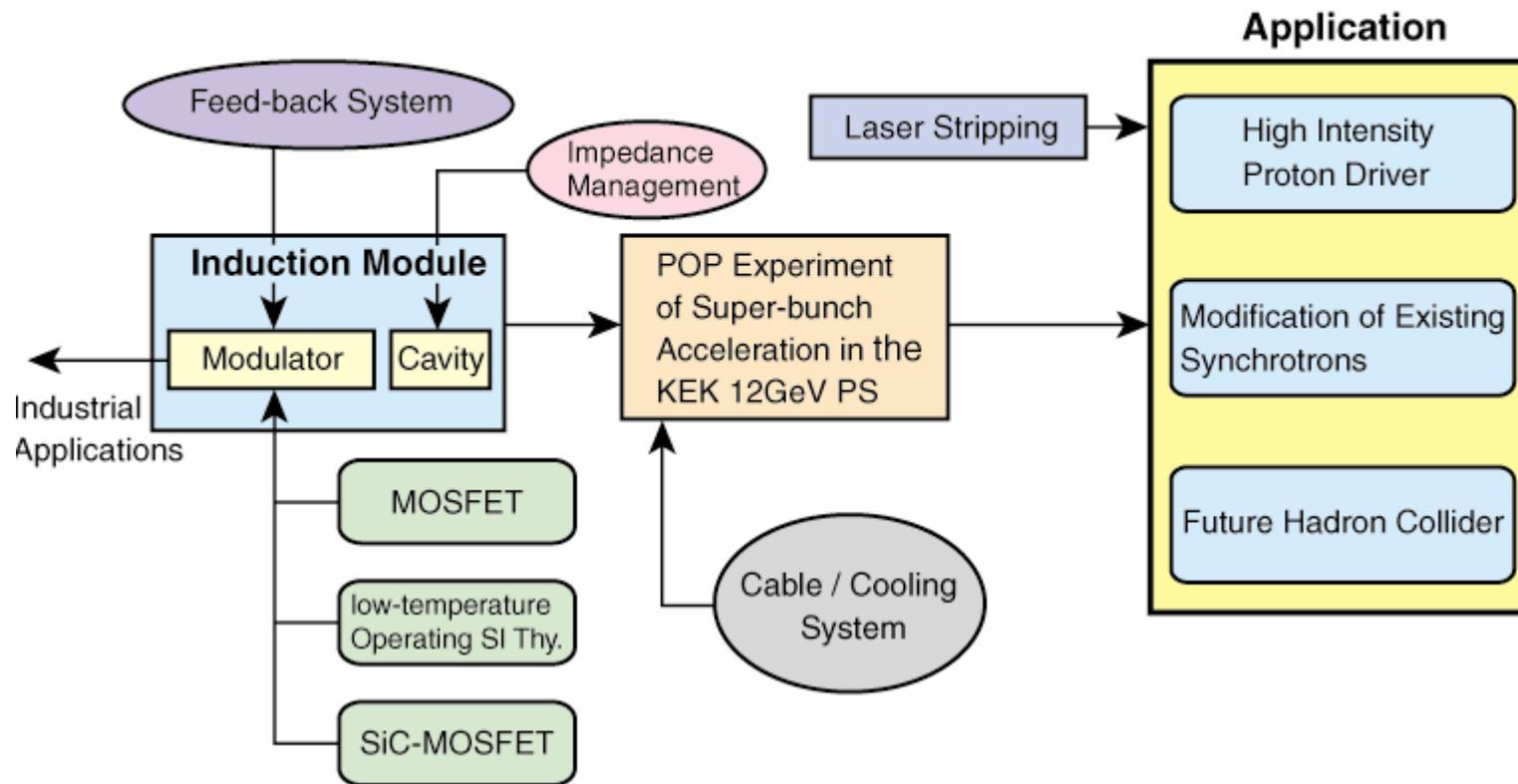
Accelerates by the long pulse induction unit.

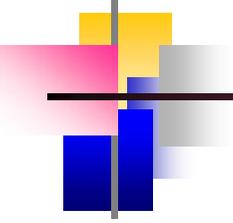


Present Status of R&D works at KEK & Road Map to IS & Collider

	1999~2001	2002	2003	2004	2005	2006~
Switching element MOSFET SI Thyristor	2kV, 100kHz -----> 3kV, 200kHz ----->	V=2.5kV, f=1MHz, t=300nsec ----->	SiC-MOSFET SI Thy. in liq. N temp. ----->	----->	----->	For Induction Synchrotron & Super-bunch Hadron Collider
Core material Finemet Co-amorphous	B-H characteristics Loss measurement					
Modulator	Circuit development	R&D #2 Assemble Optimization of circuit	Step1 Construction of devices for Accel.	Step2 Construction of devices for Accel./Confinment	Step3 Construction of devices for Accel./Confinment	
Cavity	Design, heat calculation	R&D #2 Cooling Impedance Meas.	Step1 Construction of devices for Accel.	Step2 Costruction of devices for Accel./Confinment	Step3 Costruction of devices for Accel./Confinment	
Feedback System		----->				
Utility			----->	----->		
Install/Exp.			----->	----->	----->	----->
Finantial support	R&D support at KEK and small grant	Operation fund of KEK and small grant	----- US-Japan	Grant from Gov. (expected)	-----	-----

Outline of R&d Project in Japan





Summary.

- ☀ The concept of Induction Synchrotron has been briefly reviewed.
- ☀ The Superbunch acceleration scheme has discussed to increase the beam intensity in the current/future accelerators.
- ☀ R&D works to realize the superbunch acceleration has been introduced, providing key basic information.

Real size induction units driven by the high repetition rate modulator is now testing.

The first demonstration of superbunch acceleration is scheduled in the KEK 12GeV PS.