# Recent developments on Pulsed Power Sources in Indus Accelerators

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# Recent developments on Pulsed Power Sources in Indus Accelerators

1. Few upgrades and additions were planned for Indus 2 storage ring

2. Indus 2 has been equipped with vertical pinger to study the beam dynamics

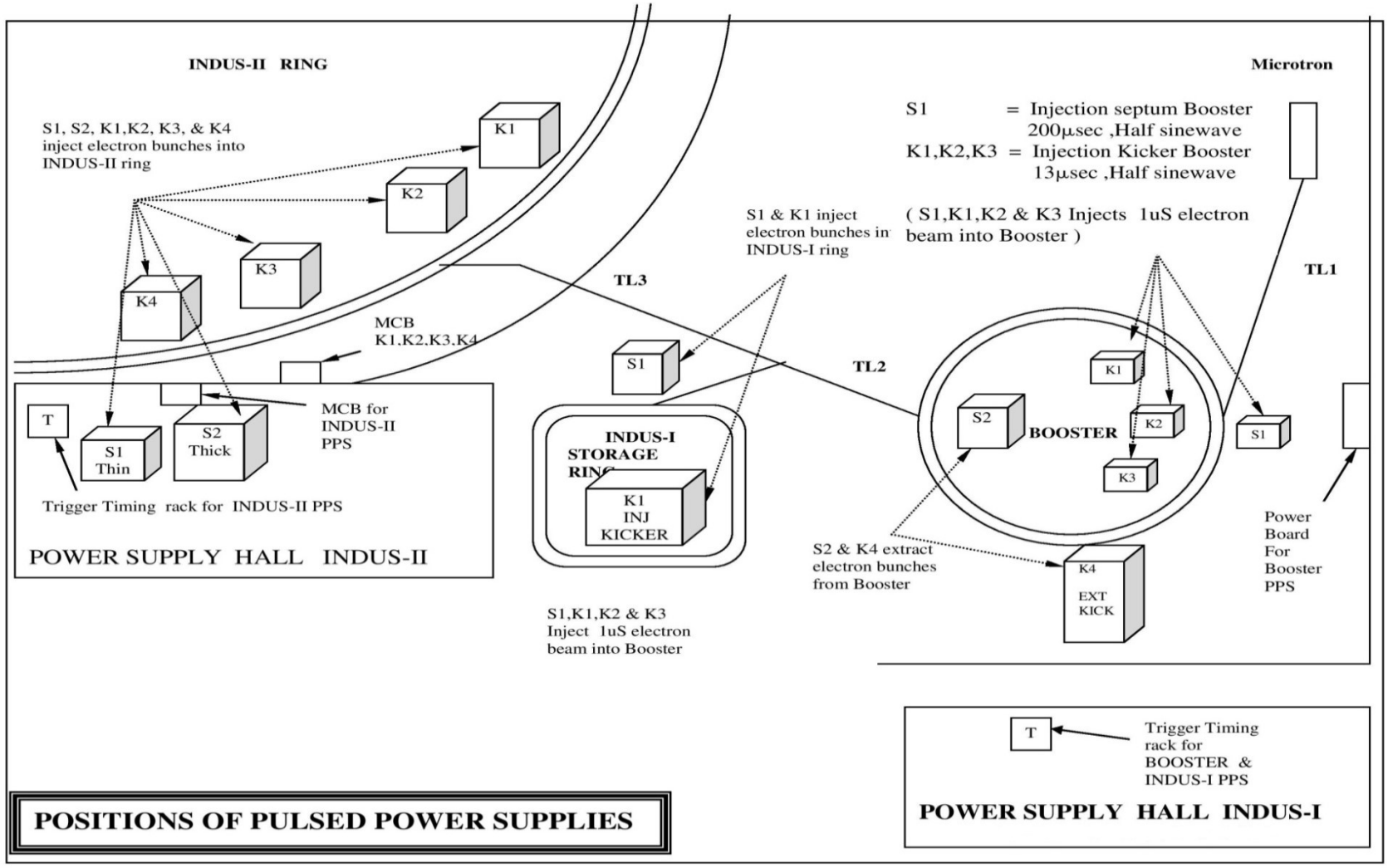
3. Equipping Indus 2 with horizontal pinger is also planned in 2021

4. An upgraded injection pulser for Indus-2 injection kickers has been tested

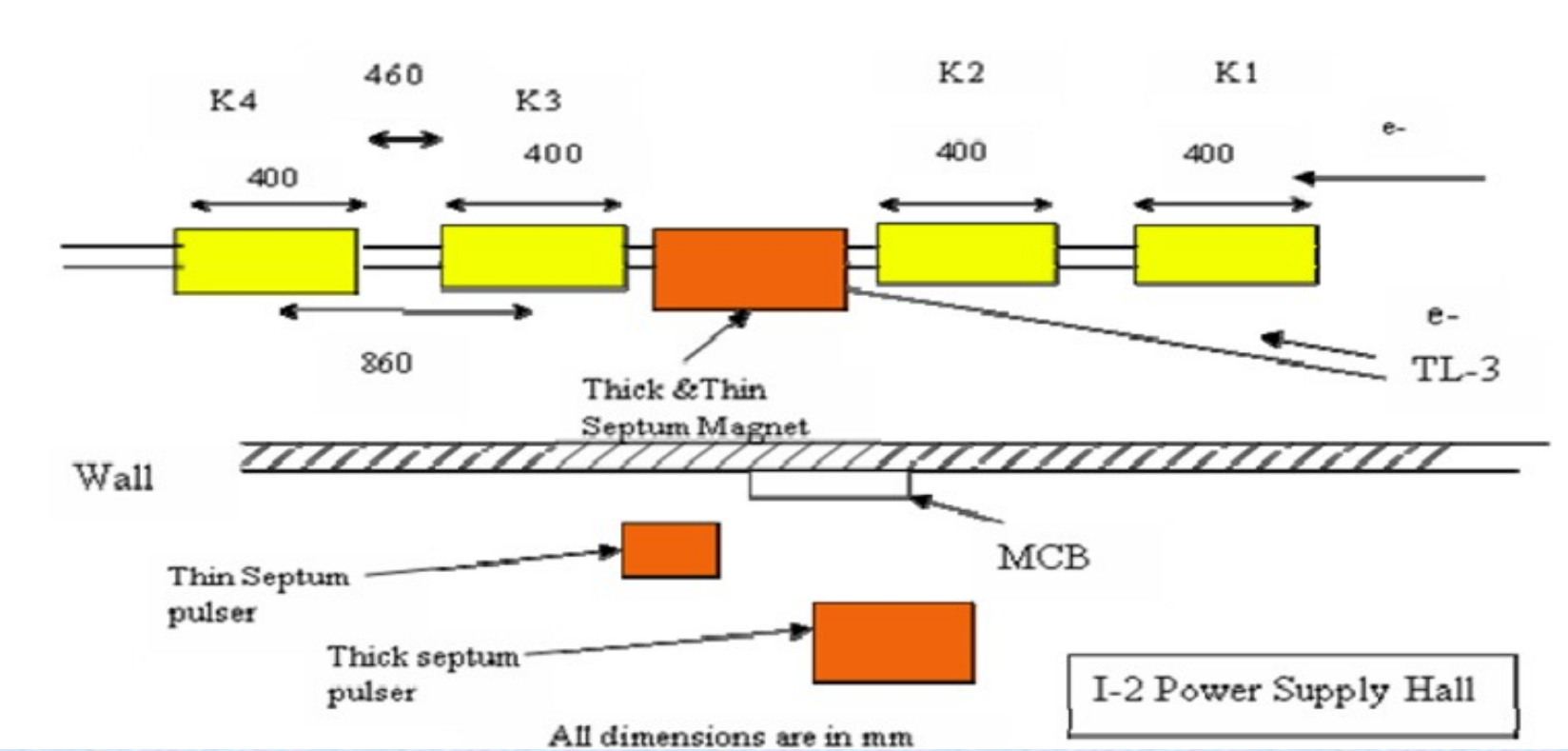
# Outline of talk

1. Pulsed power sources in Indus complex
2. Need and background of the developments
3. Technical details of the developments carried out
4. Outcomes and present status
5. Future plans
6. Conclusion

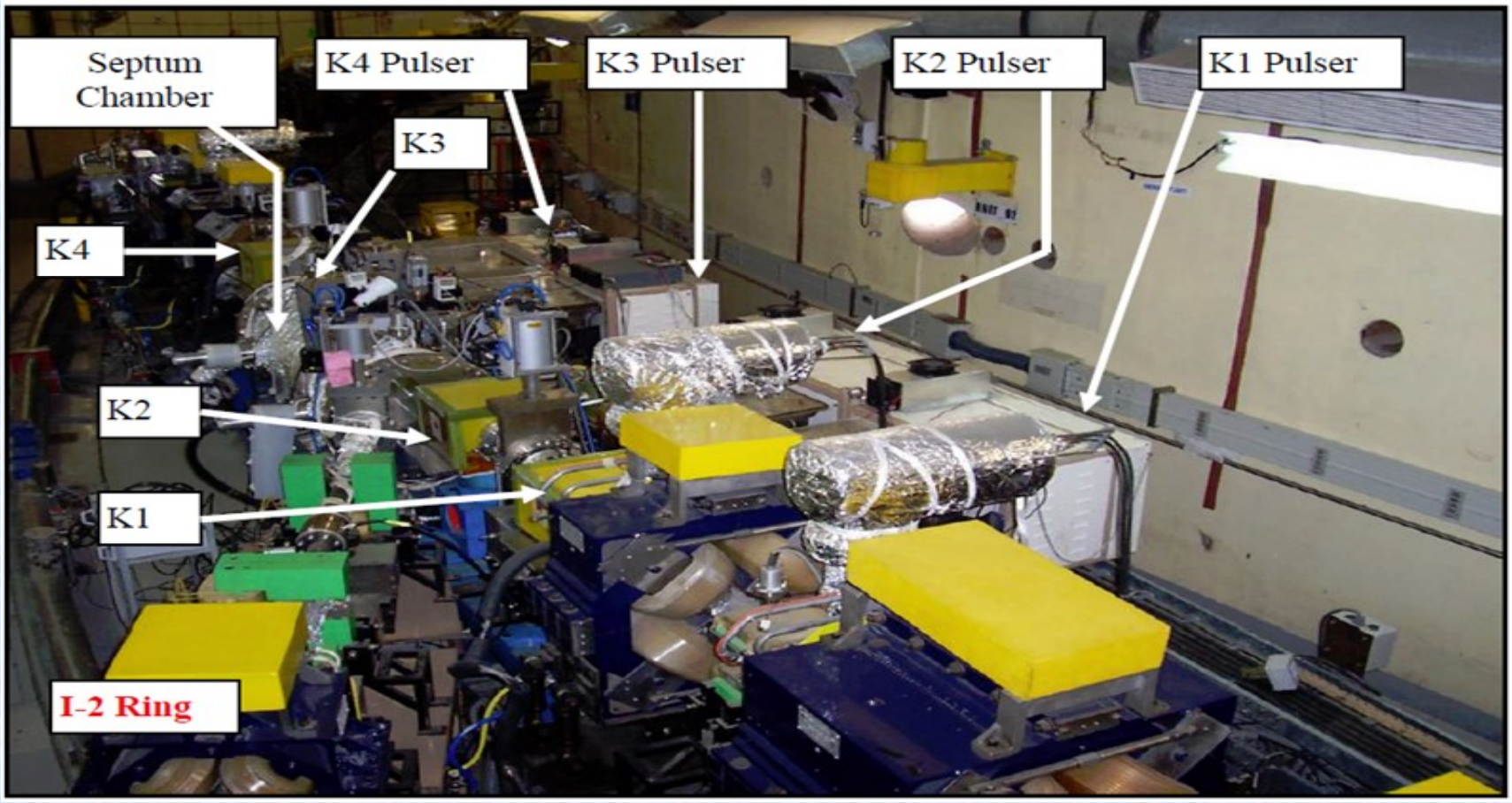
# Pulse Power Supplies in Indus Machine



# Kicker and Septum Location in Indus -2



# Indus -2 : Injection section



• **Upgraded Injection Kicker Pulser for Indus 2 Injection Kickers : Background and Need**

• Existing Indus 2 kicker pulsers use Thyratron as high voltage switch.

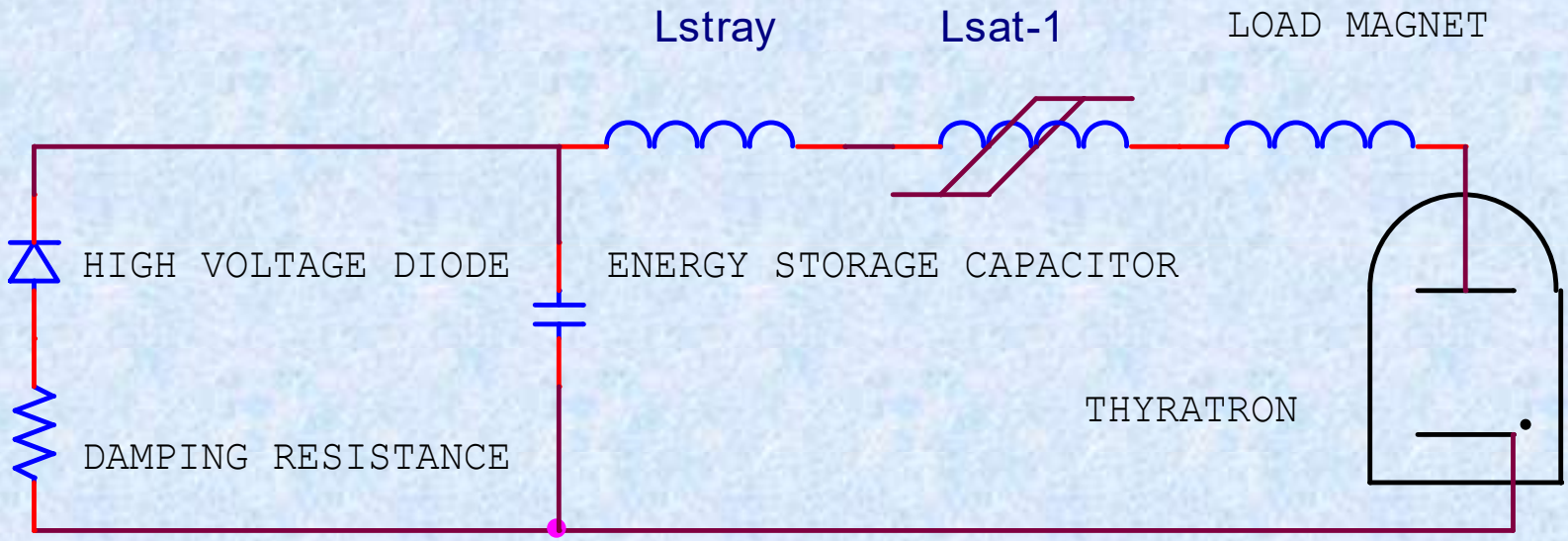
• A pre-charged capacitor is discharged into kicker magnet to produce 3 usec., 10 kA sine pulse current in kicker magnet.

• Thyratron and pulse power circuit are housed in large oil assemblies very near to kicker magnet to keep Lstray low.

• A resistor diode series circuit across pulsed capacitor to limit reverse voltage on thyratron.

• Working Voltage of Pulser : 27kV @ 10kA, 3usec.

# Circuit Schematic : Existing Pulser




CIRCUIT SCHEMATIC FOR INDUS-2 PS

# • The Issues and Scope of improvement

• Large oil assemblies inside the ring

• Difficult to maintain and replace the components if required

• Extremely difficult to tune the pulse power circuit for component drifts over time, to achieve matched waveforms

• Large oil assemblies, Large stray inductances, Higher working voltages

## •Scope of improvement

1. Possibility of realising the design at lower working voltages

2. Lower working voltages, low voltage rated components, smaller size and compact air insulated assemblies

3. Ease of maintenance, ease of tuning for matching of kickers

4. Low stray inductance leads to still lower working voltages

- The New Design : Lowering the working voltage

- Selective damping by introduction of magnetic switch in resistor diode path

- Redesign of damping resistor to maintain the reverse voltage on thyratron

- Possibility of increased rise time of pulse current for same half sine pulse width (3us)

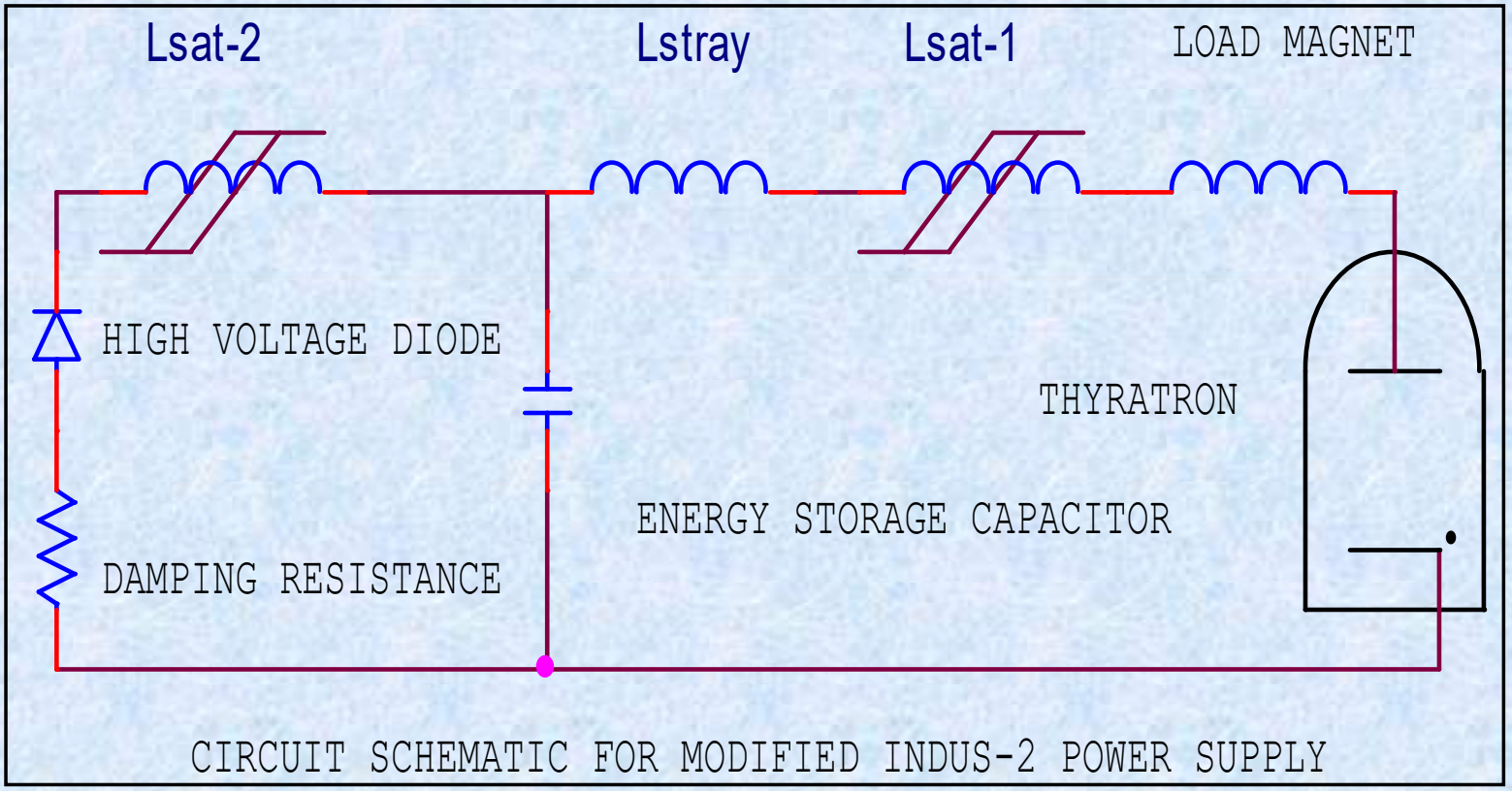
- Lowering of working voltage for same pulse current

# Recent developments on Pulsed Power Sources in Indus Accelerators

- Possibility of use of lower voltage rated components
- Smaller Pulse capacitor size, lower ESL, compact assembly
- Co-axial assembly for thyratron switch and pulse power circuit further lowers the stray inductance
- This leads to further reduction in working voltage

# Recent developments on Pulsed Power Sources in Indus Accelerators

- Pulse Power Circuit : with upgraded design



# Pulse Capacitor voltage and load current waveforms : with upgraded design

# Power source with kicker magnet : with upgraded design

# Comparison of existing and upgraded pulse source

| S.No. | Pulse Parameter | Existing Pulser | New Pulser |
|---|---|---|---|
| 01 | Pulse Width | 03 us | 03 us |
| 02 | Peak Current | 06 kA | 06 kA |
| 03 | Magnet Inductance | 0.82 uH | 0.82 uH |
| 04 | Pulse Circuit Capacitance | 0.35 uF | 0.70 uF |
| 05 | Operating Voltage | 14.75 kV | 08 kV |

Outcome and present status : Power source has been developed as per new design. Same load current could be achieved at nearly half of the working voltage w.r.t. existing power source. This has validated the upgraded design.

Conclusion : New design was quite effective in reducing the working voltage. An air insulated pulser could be realised with this design

Future Plans : With the reduced working voltage, possibility of realising this source with semiconductor switch exists and the same will be explored. Semiconductor switch based pulse source is further going to deliver many advantages over thyratron base switch. Some of the major characteristics of a semiconductor based switch are (i) No drift with time (ii) No auxiliary power supplies required (iii) easy to maintain and replace (iv) low jitter, repeatable performance (v) much easier availability with multiple sources etc.

## Equipping Indus 2 with Pinger Kicker System

1. Lately it was decided to equip Indus 2 with two Pinger Kicker systems.

2. Pinger kicker system will consist of two types of kickers namely horizontal and vertical pinger kicker.

3. These pinger (kicker) magnets are energized by two separate power sources. These kickers will generate betatron oscillation in the stored beam (few bunches) of Indus 2 in a synchronised operation.

## Equipping Indus 2 with Pinger Kicker System

4. The kickers will act as a tool to probe the linear and non linear dynamics of the beam. The turn by turn oscillations of the beam are captured by BPMs of the ring.

5. Two pulse power sources to energize these kicker magnets respectively has been developed.

6. Vertical pinger kicker system has already been installed in the ring

## Equipping Indus 2 with Pinger Kicker System

7. Horizontal pinger power supply development has also been completed and the same has been tested with kicker magnet in lab.

8. Installation and commissioning of horizontal kicker system in Indus 2 ring is also planned shortly.

# Fast power supplies for Pinger Magnets

1. Two pinger magnet power supplies to energize the two kicker magnets, one in vertical and other in horizontal plane.

2. The vertical and horizontal pinger magnet power supplies will deliver half sine current pulses of peak current 5.5 kA and 2.6 kA respectively with a pulse width of less than1 micro second.

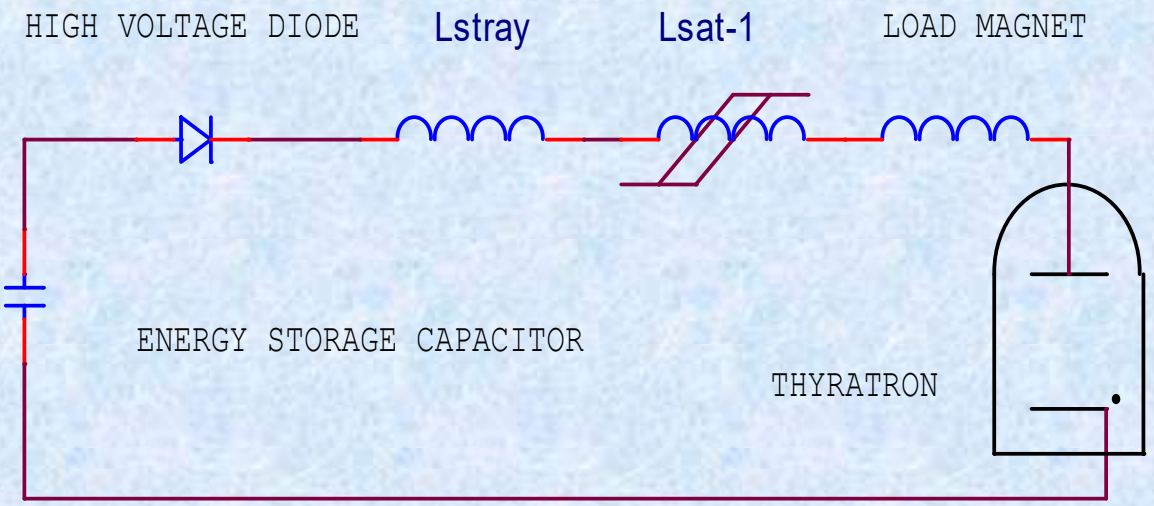
## Fast power supplies for Pinger Magnets

3. Large peak current with a very short pulse (large di/dt) requires a very compact design of pulse power circuit to keep stray inductances minimum and thus reducing the working voltage.

4. Pulse power circuit was installed near to magnet to achieve the above objective.

# Recent developments on Pulsed Power Sources in Indus Accelerators

## Pulse Power Circuit for Pinger kicker Pulse source

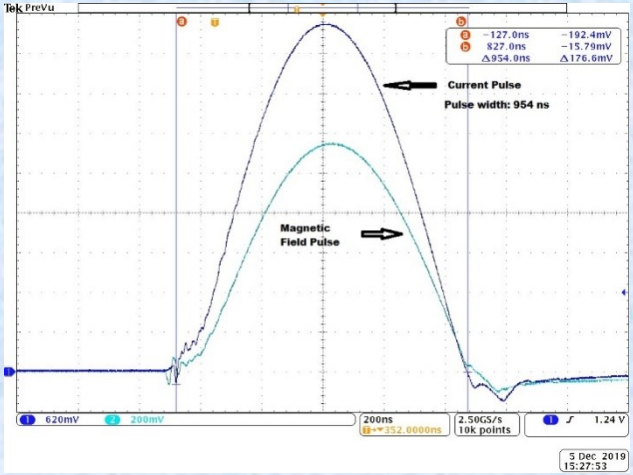


# Vertical Pinger Kicker in Indus 2 ring

A power source to energize the vertical pinger magnet was developed. It delivers a half-sine wave current pulse of peak current 5.5 kA in the pinger magnet load with a pulse width of less than1 μs. power source was installed in Indus 2 ring and integrated with the magnet load and remote control system.


Vertical Pinger Magnet Pulse Source

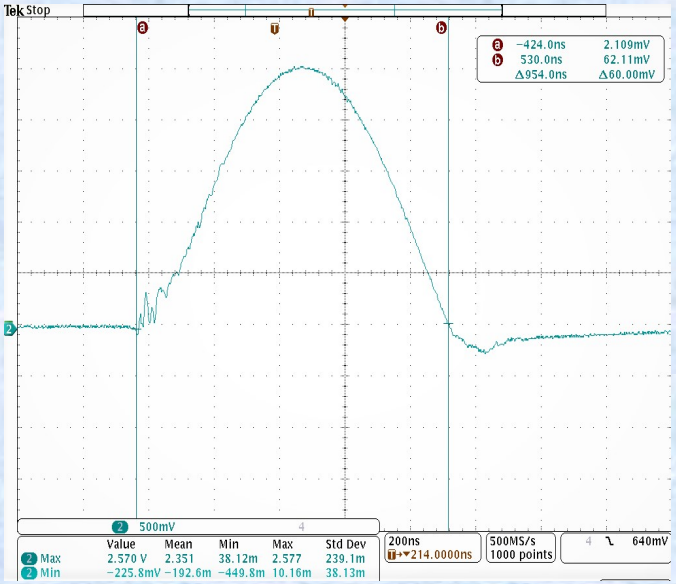
Vertical Pinger Kicker installed in Indus 2 ring




Vertical Pinger Magnet Power Source current and field waveform

# Horizontal Pinger Kicker Power Source

Developed power supply




Load Current waveform

## Pinger Kicker Power Sources : outcome and present status

1. Two pulsed power sources have been developed to deliver the required less than 1microsecond long pulses of 5.5 kA and 2.6 kA for energizing the vertical and horizontal pinger magnets respectively.

2. Vertical pinger kicker system has been installed and commissioned in the ring

3. Horizontal pinger kicker system is to be installed and commissioned in the ring soon.

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# Thank You