ENERGY TRANSFER EFFICIENCY OF NANO-SECONDS PULSED POWER GENERATOR FOR NON-THERMAL PLASMA PROCESSING

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Background

NO_X removal → Conventional Pollution Control Method → Negative Situation

- SCR
- Electron beam
- Lime-gypsum

- Low energy efficiency
- High cost equipment

O_3 generation → Attracting the attention for strong oxidation power

Method

Non-Thermal Electric Discharge Plasmas

- Dielectric Barrier Discharge (DBD) → 10%
- Corona Discharge → Less than 10%

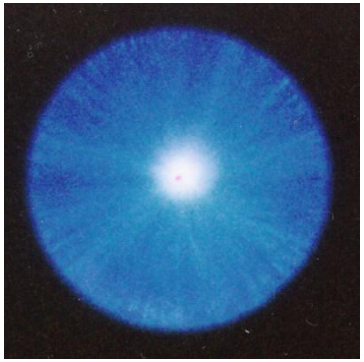
Low Energy Transfer Efficiency

Non-Thermal Plasma Processing using Pulsed Discharge

General Pulsed Discharge (Pulse duration > 100ns)

- Pulse discharge system -

Pulsed discharge



Pulse generator

Energy loss by compression circuit

Discharge **30%**

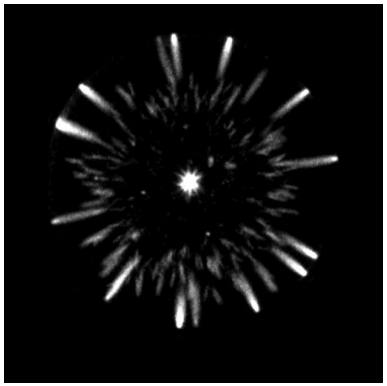
Energy loss by **Impedance mismatching** and **Gas heating**

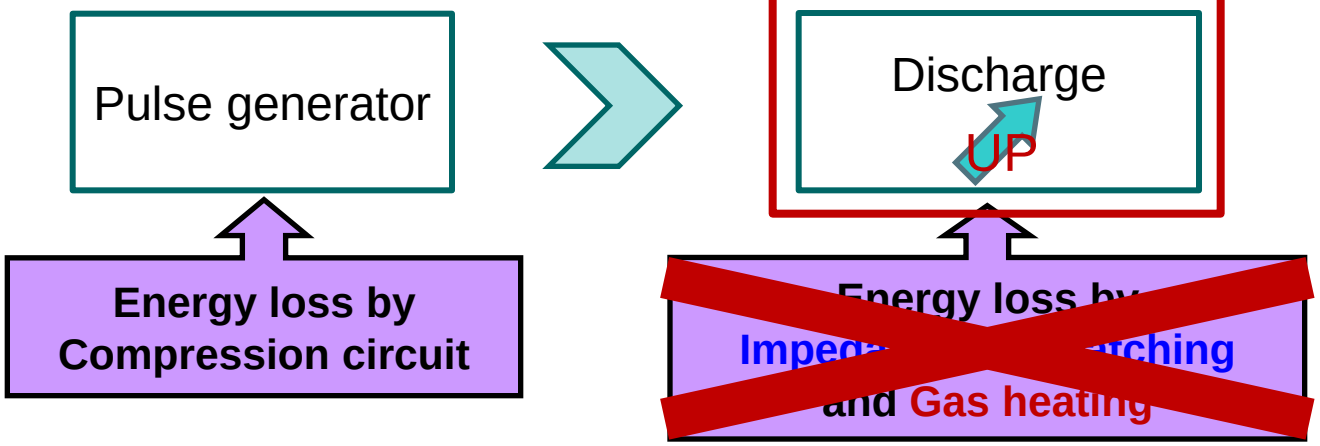
	Pulse discharge plasma		NS pulse discharge plasma
Pulse duration	**100 ns**		**5 ns**
Discharge phase	**Streamer**	**Glow**	**Streamer only**
Plasma impedance	**5-17 kΩ (L=10 mm)**	**2 kΩ (L=10mm)**	**0.2 kΩ (L=1000 mm)**
Temperature rise of gas	**None**	**150 K**	**None**

Nano-Seconds (NS) Pulsed Discharge (Pulse duration = 5ns)

- Pulse discharge system -

NS Pulsed discharge

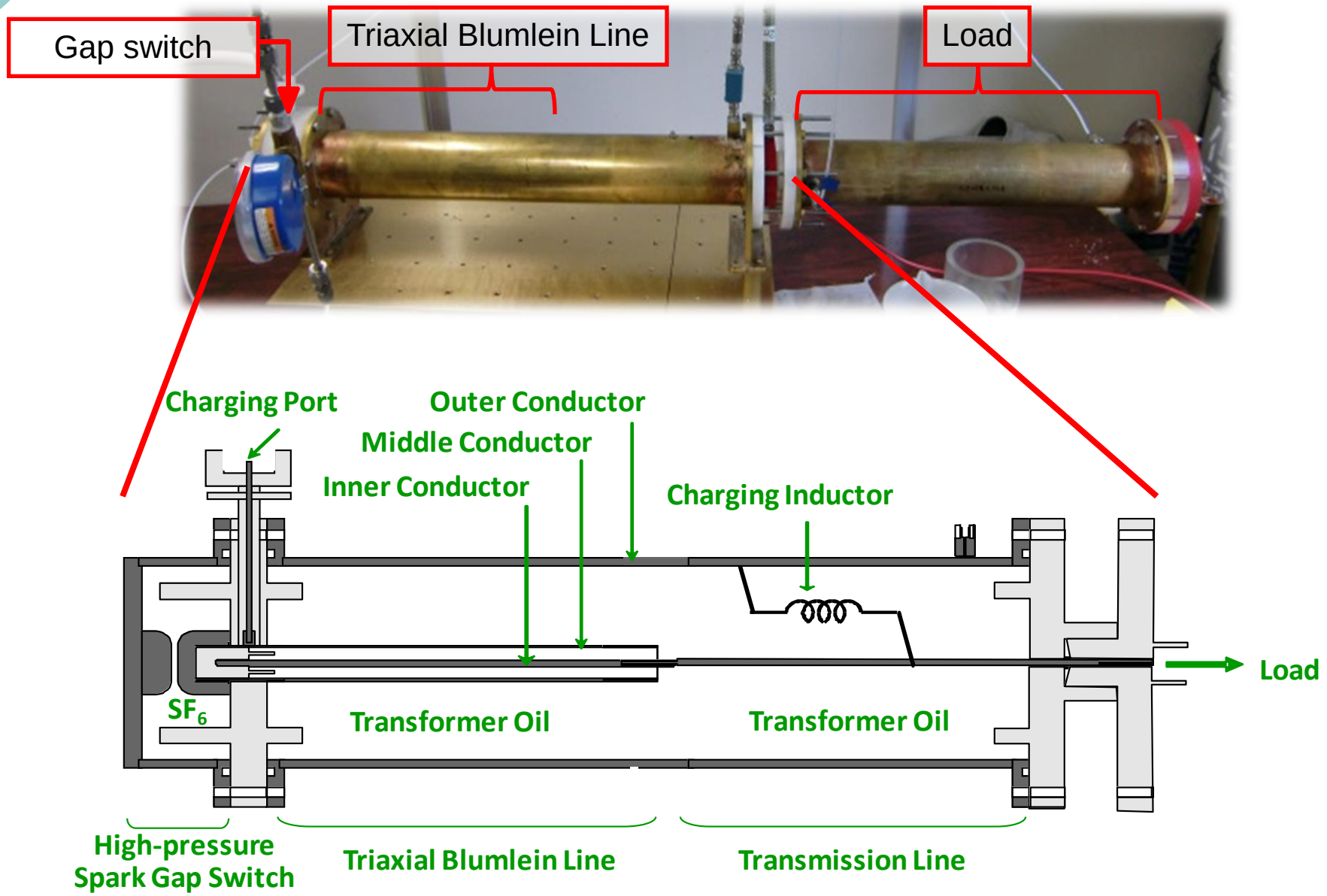




To reduce Impedance mismatching and Thermal loss

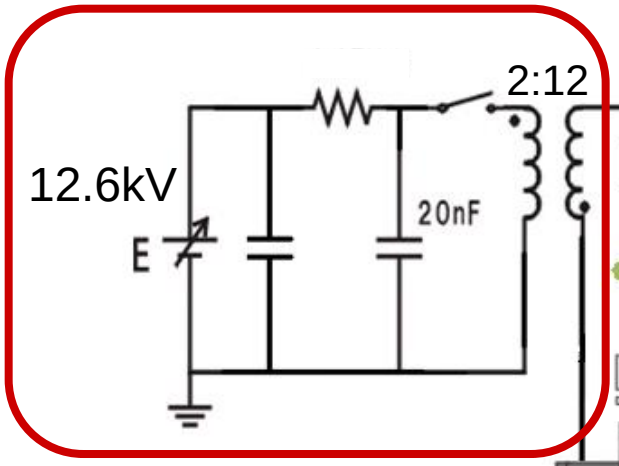
	Pulse discharge plasma		NS pulse discharge plasma
Pulse duration	**100 ns**		**5 ns**
Discharge phase	**Streamer**	**Glow**	**Streamer only**
Plasma impedance	**5-17 kΩ (L=10 mm)**	**2 kΩ (L=10mm)**	**0.2 kΩ (L=1000 mm)**
Temperature rise of gas	**None**	**150 K**	**None**

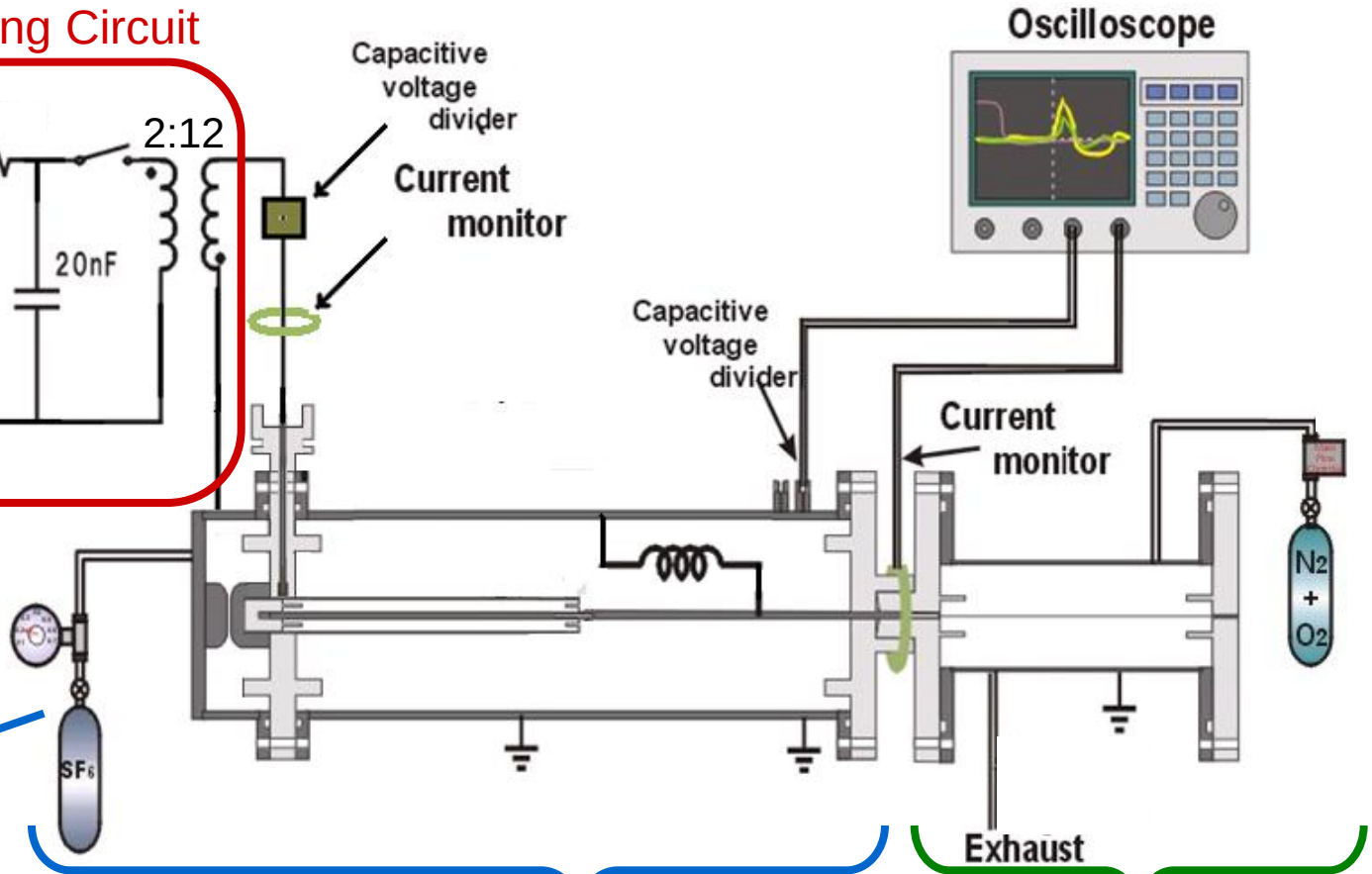
NS Pulsed Generator (NS-PG)



Experimental Set-up

NS-PG Charging Circuit





SF_6 gas pressure varied from 0.2Mpa to 1.2Mpa. V_{out} was controlled by varying SF_6 gas pressure.

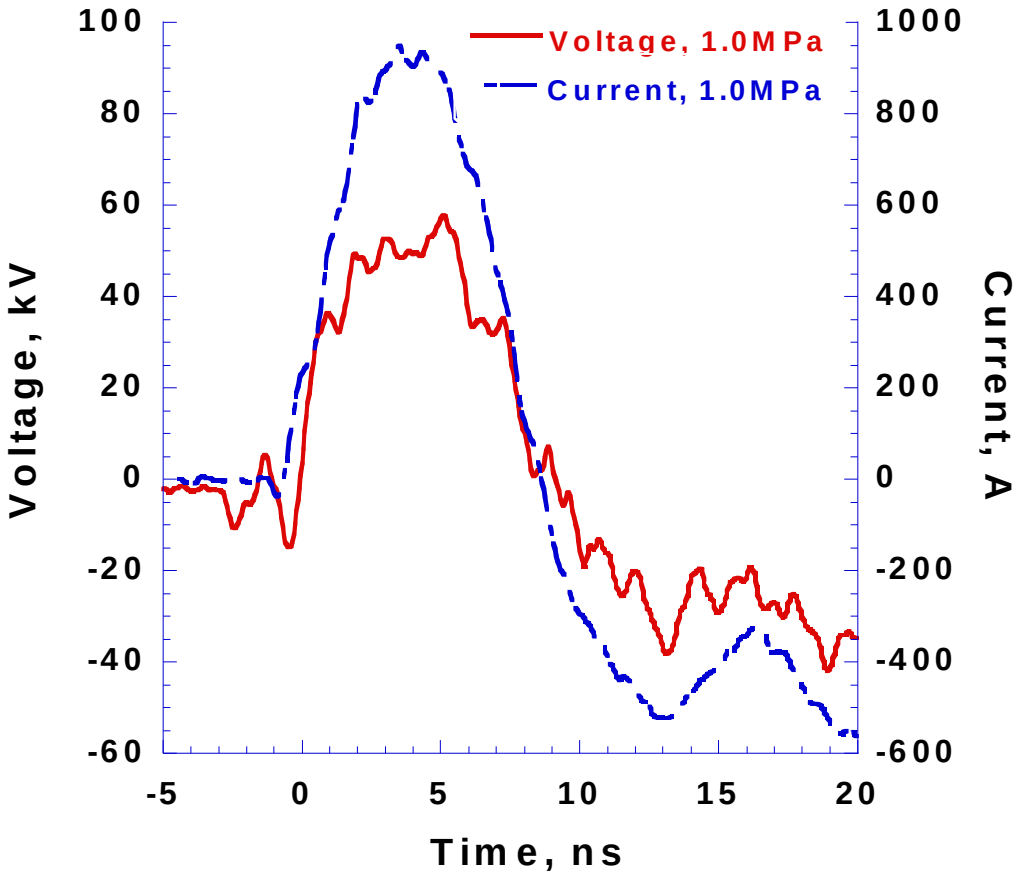
NS-PG

Pw = 5ns
Z = 50Ω

- Low Inductance Resistive Load (50Ω)
- Discharge Reactor Load

Low Inductance Resistive Load

- Output Voltage and Current to 50Ω Load -

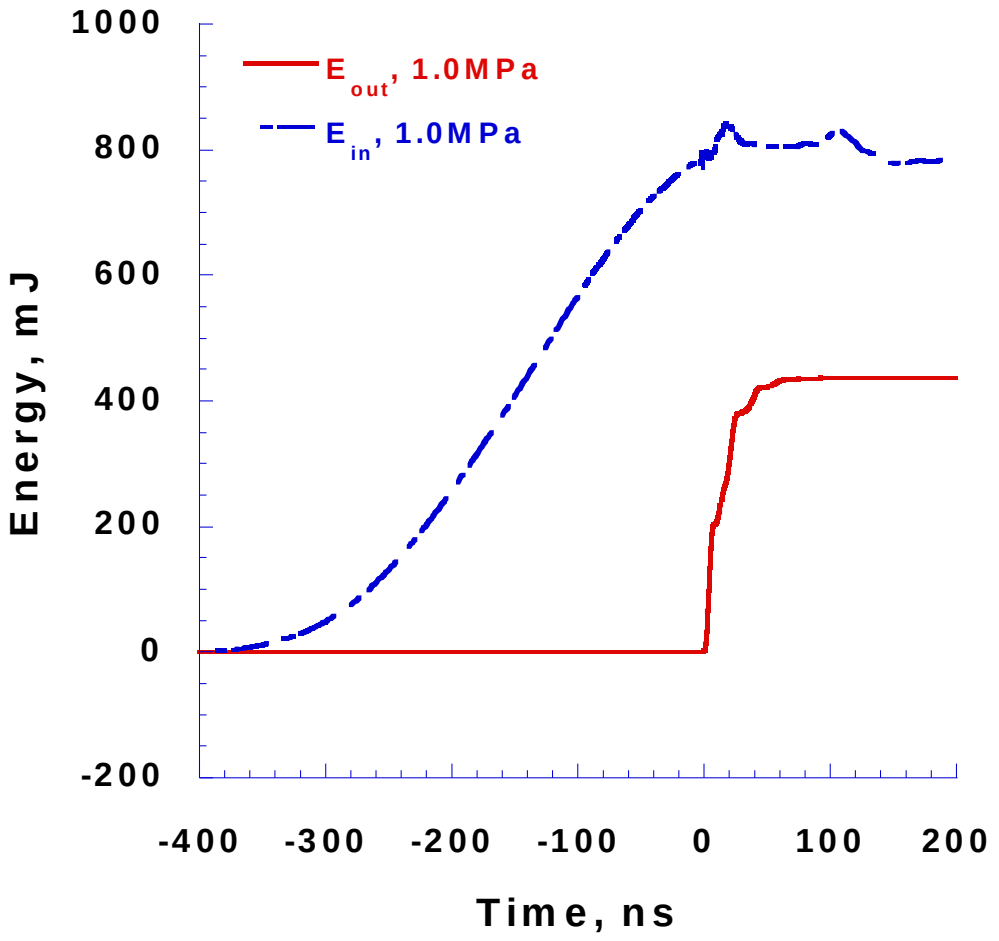


-Condition-
SF_6 Gas Pressure : 1.0MPa
DC Supply Voltage : 12.6kV
Output Polarity : Positive

- Peak Voltage : 57.8kV
  (Proportion to Gas Pressure)
- Peak Current : 879.4A
  (Proportion to Gas Pressure)
- Full Width at Half Maximum (FWHM) : 5ns

Low Inductance Resistive Load

- Stored energy to NS-PG per pulse, E_{in},
and output energy to 50Ω load per pulse, E_{out} -



-Condition-
SF_6 Gas Pressure : 1.0MPa
DC Supply Voltage : 12.6kV
Output Polarity : Positive

$$E_{in} = \int V_{in} \times I_{in}\, dt \quad (1)$$

$$E_{out} = \int V_{out} \times I_{out}\, dt \quad (2)$$

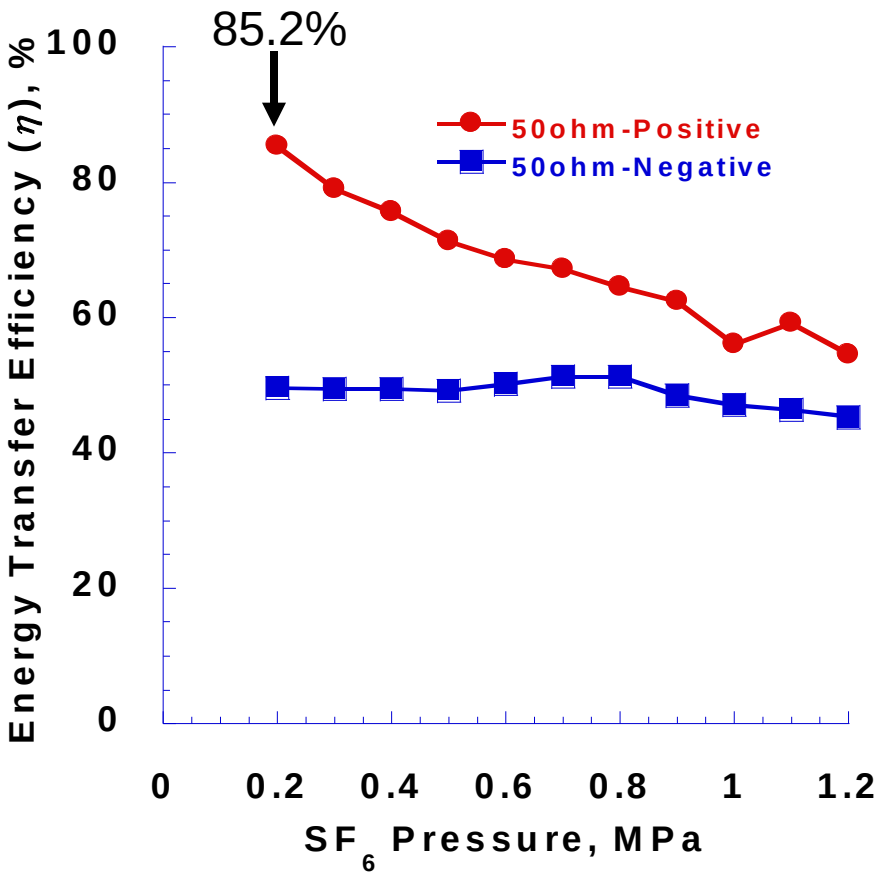
V_{in} and I_{in} :
Voltage and Current to NS-PG
V_{out} and I_{out} :
Voltage and Current to load

Energy Transfer Efficiency

$$\eta = \frac{E_{out}}{E_{in}} \times 100 \ (\%) \quad (3)$$

Low Inductance Resistive Load

- Energy Transfer Efficiency, η -



Output of Positive

➔ **Negative Charge into SGS**

SF_6 Gas Pressure **up**

Voltage Applied to NS-PG System **up**

Corona Loss **up**

Energy Transfer Efficiency **down**

- Switching Loss of SGS
- Impedance Mismatching

(Calculated output impedance is 60Ω)

Output of Negative

➔ **Positive Charge into SGS**

Large Corona Loss occurs even at lower SF_6 gas pressure.

Discharge Reactor Load

- Output Voltage and Current to Discharge Load -

-Condition-

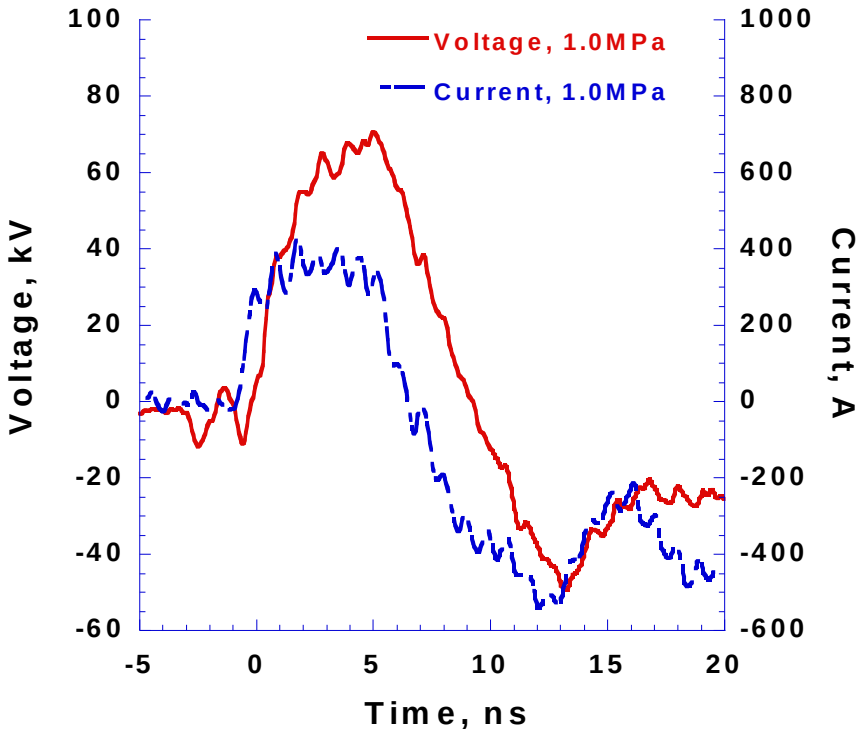
SF_6 Gas Pressure : 1.0MPa

DC Supply Voltage : 12.6kV

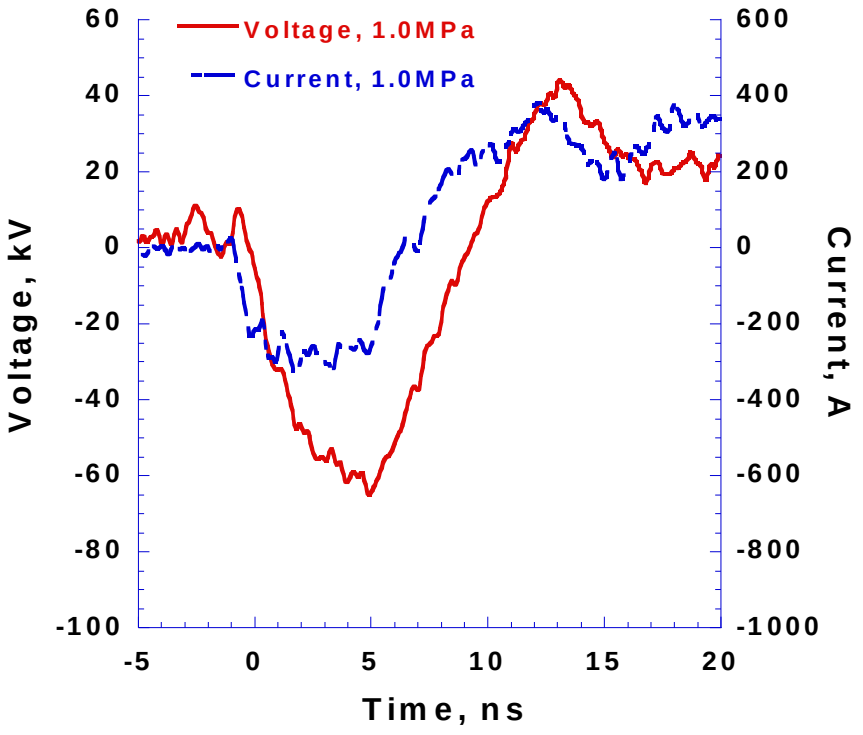
N_2 : 79%, O_2 : 21%

•Peak Voltage : 69.3kV (Proportion to Gas Pressure)

•Peak Current : 374.0A (Proportion to Gas Pressure)



(a) Positive Voltage Polarity



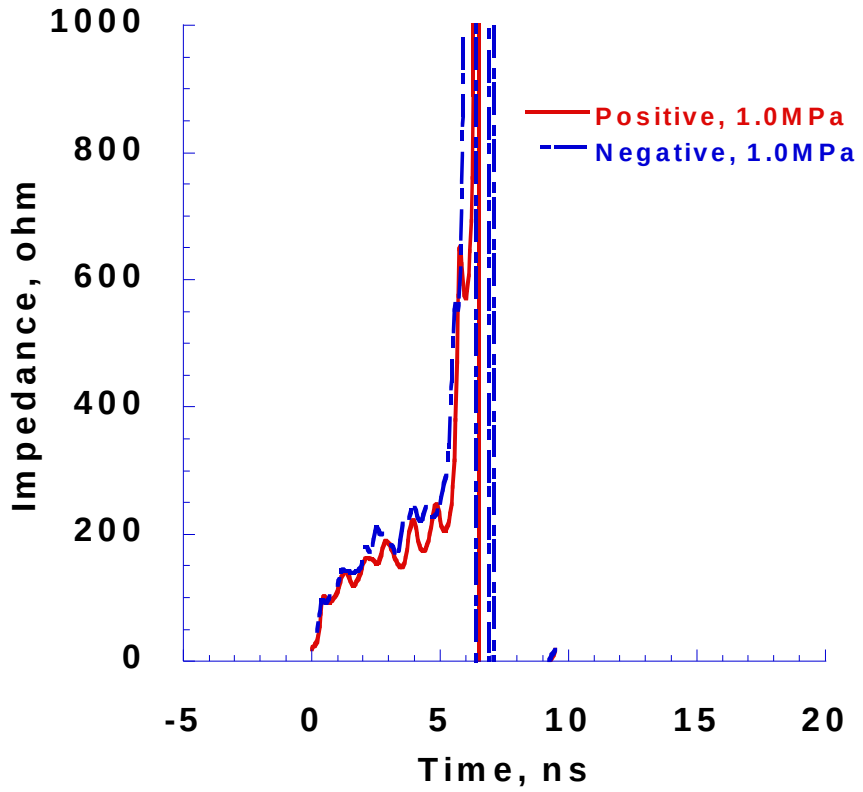
(b) Negative Voltage Polarity

Discharge Reactor Load

- Plasma Impedance of Discharge Load -

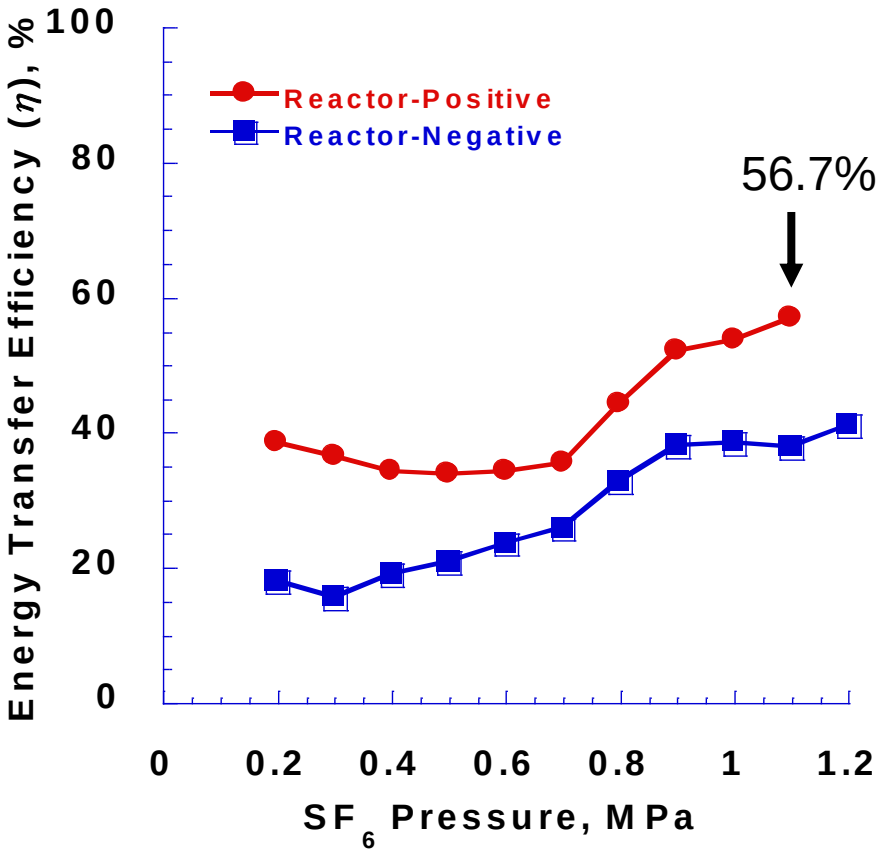
-Condition-
SF_6 Gas Pressure : 1.0MPa
DC Supply Voltage : 12.6kV
N_2 : 79%, O_2 : 21%

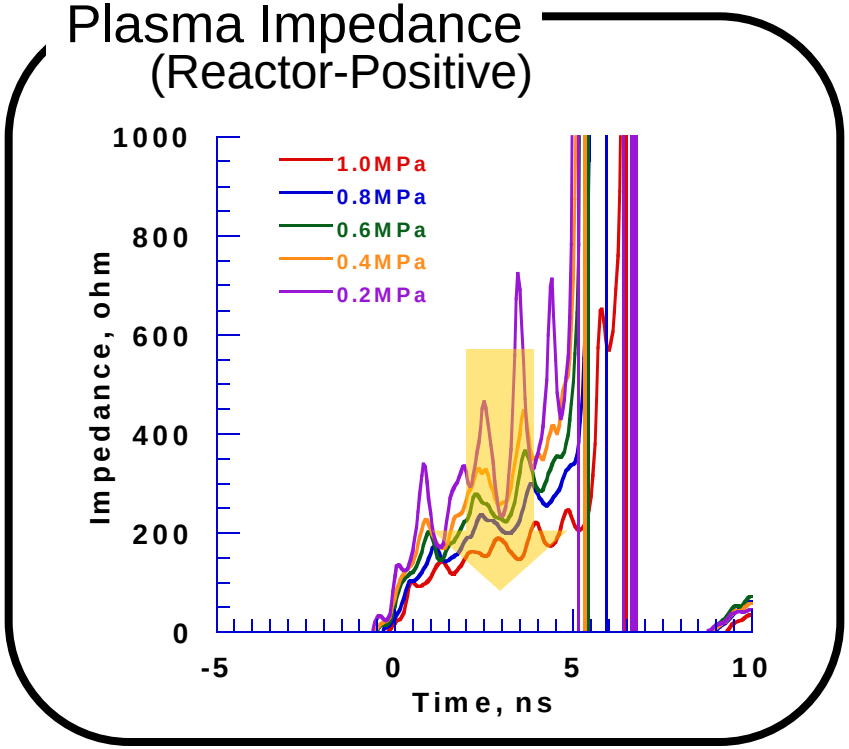
The discharge characters are similar in both voltage polarities.



Discharge Reactor Load

- Energy Transfer Efficiency, η -





SF_6 Gas Pressure **up**

⇒ Plasma Impedance **down**

⇒ Energy Transfer Efficiency **up**

Conclusion

Energy transfer efficiencies from NS-PG to load were studied on a resistive load and a discharge reactor load, in both cases of positive and negative voltage polarities.

The maximum energy transfer efficiency was **85.2 %** and **56.7 %** in case of resistive load and a discharge reactor, respectively.

Further energy transfer efficiency can be achieved by optimize the configuration of discharge reactor.

Output voltage polarity \ Load		Low inductance 50 Ω resistor		Discharge reactor	
Positive	$V_{out\text{-}peak}$	21.5 kV	59.2 kV	20.4 kV	74.4 kV
	E_{out}/E_{in}	85.2 %	59.2 %	38.4 %	56.7 %
Negative	$V_{out\text{-}peak}$	-23.0 kV	-55.6 kV	-26.2 kV	-68.3 kV
	E_{out}/E_{in}	49.6 %	46.4 %	17.8 %	37.9 %

up Goal 100%

Thank you for your attention.