Atmospheric pressure plasma jet generation and impedance measurement

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University of Texas at Dallas

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Introduction → Dallas

Location in Dallas County and the state of Texas

Location in the United States

Coordinates: 32°46′58″N 96°48′14″W

Flag of Dallas

Seal of Dallas


The Dallas Morning News

KENNEDY SLAIN ON DALLAS STREET

JOHNSON BECOMES PRESIDENT

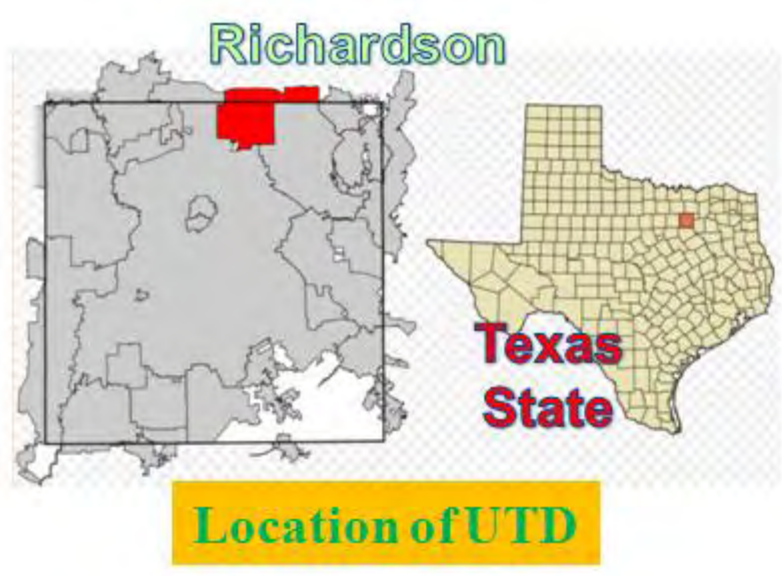
Place of interest

Most famous: sixth floor museum

About the city of Dallas

- 3rd largest city in Texas State
- 8th largest cityin the United States
- Population ~ 1.4 million by Jan. 1, 2010
- A humid subtropical climate
  - hot, humid summers
  - cool winters
- Primary airport → DFW airport

Introduction → UTD



University of Texas at Dallas

- A public research university in The University of Texas System.
- The UTD main campus is located in Richardson, Texas, United States
- Is best known for its computer science, natural science, engineering, cognitive science, mathematics, and MBA programs

UTD Residence Hall

UTD Library

International Training Program

- **Period:** 2 months → Jan.9 --- Mar. 9, 2010
- **Research site:** NSERL → Natural Science and Engineering Research Laboratory
  3rd floor
  Prof. Lawrence Overzet
  Plasma Science and Applications Lab.
- **Living site:** dormitory → UTD Apartments furnished 2-bed room
  (shared with an Indian) A 10 minute walk to Lab.

Dining site: dining hall on the campus
or cook by yourself (30 min. walk to super market)

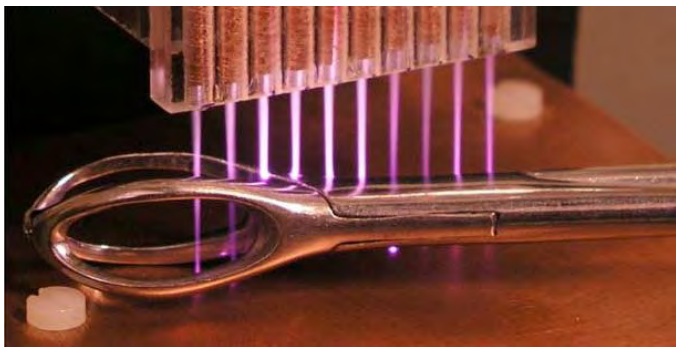
UTD Apartments

Natural Science and Engineering Research Laboratory

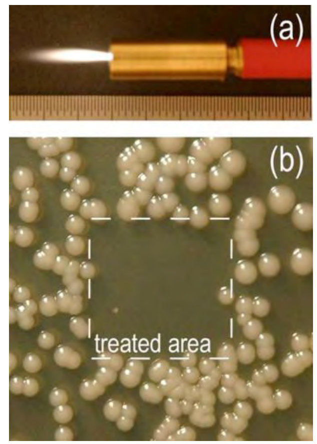
Background → CAPPJ

CAPPJ: Cold Atmospheric Pressure Plasma Jet

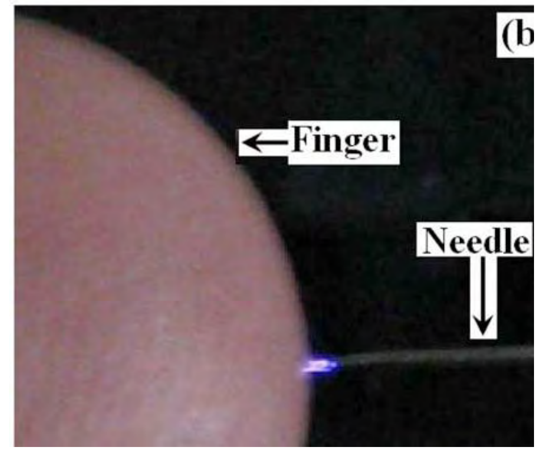
- ***Cheaper*** **&** ***more convenient*** **than low-pressure plasmas**
- ***Simple*** **configurations &** ***easy*** **operation**



Appl. Phys. Lett. 94, 021501 2009



Appl. Phys. Lett. 92, 241501 2008



Appl. Phys. Lett. vol. 95, no. 18, pp. 3, 2009

Treatment
- *3-D objects*
- *thermally sensitive materials*

+

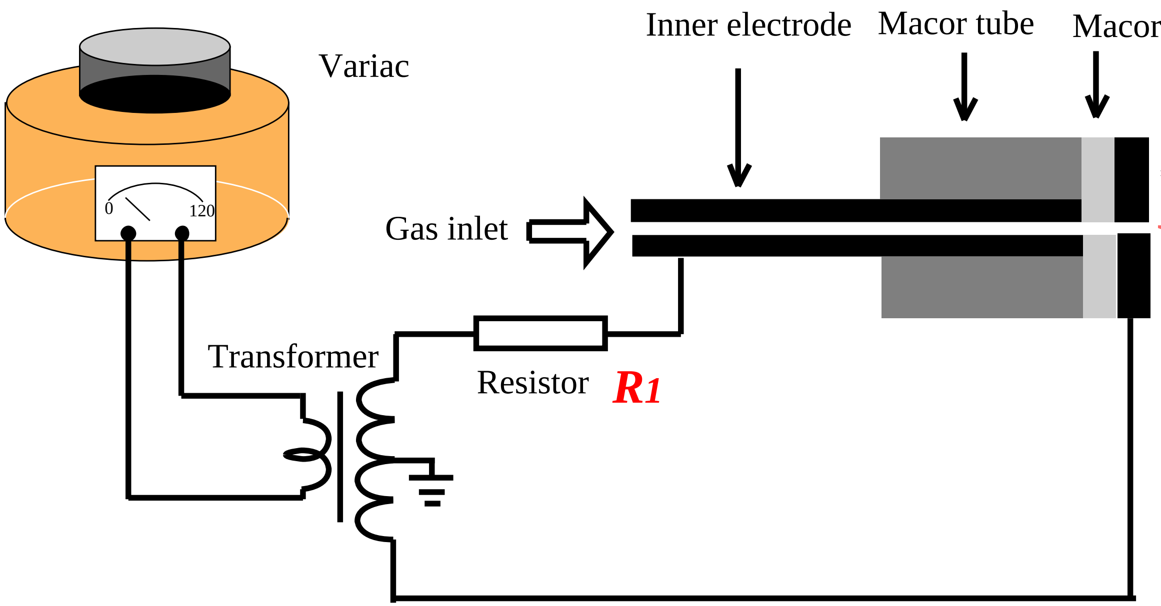
Biomedical applications

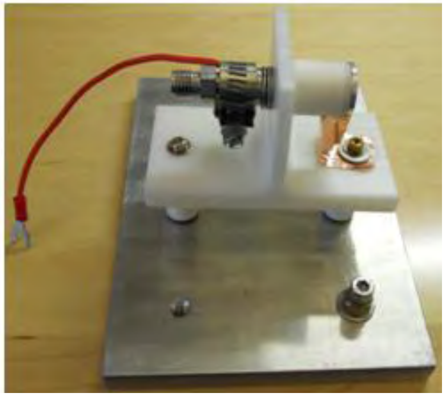
Research objective:

Find an easy way to generate N_2 APPJ and try to measure plasma impedance

APPJ generation

Schematic of the experimental setup





Design & manufacture cost ~ one month

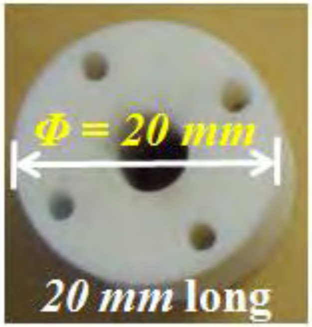
1. Variac: POWERSTAT: output voltage ~ 120 V

2. Transformer: Fransformer ***Vp-p*** **~ 6√2 kV,** ***f*** **~ 60 Hz**
a step-up transformer for neon light

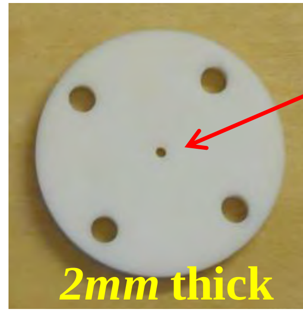
3. Gas: N_2

1. All of these are easy to get!
2. Simple to generate plasma

Electrode configuration



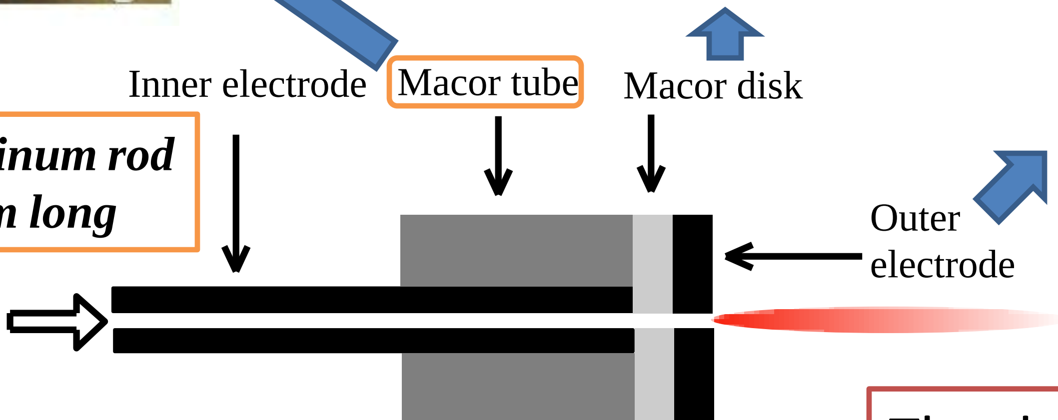
MACOR is a machineable glass-ceramic

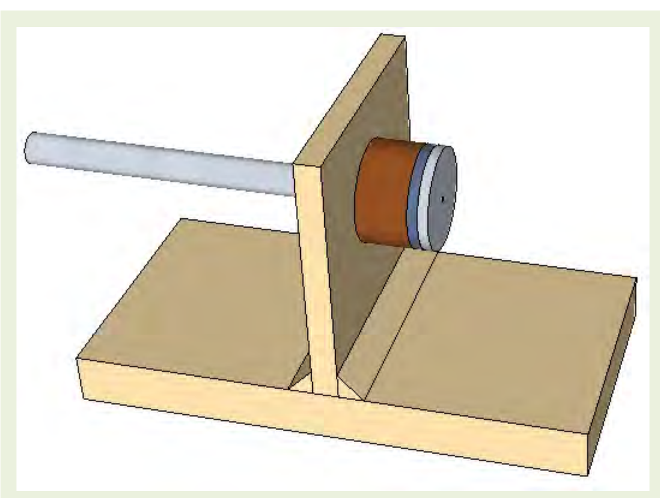


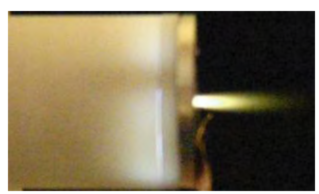
Φ = 0.8 mm **hole**

Φ = 0.5 mm
Aluminum disk

Aluminum rod
40 mm long





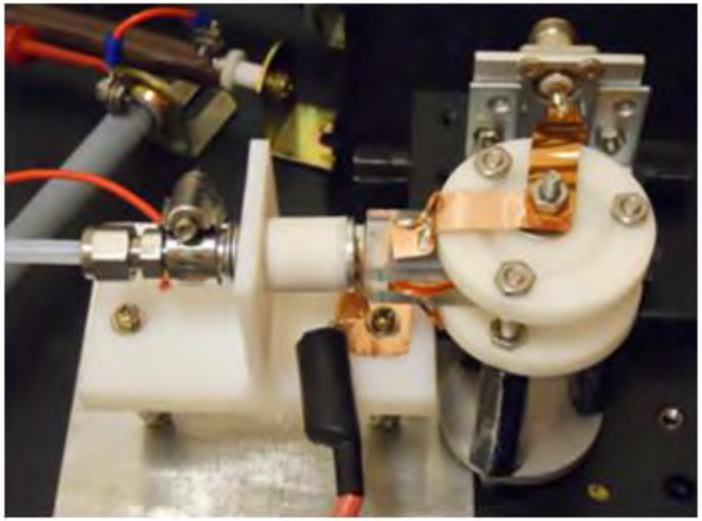


The device consists of four parts:

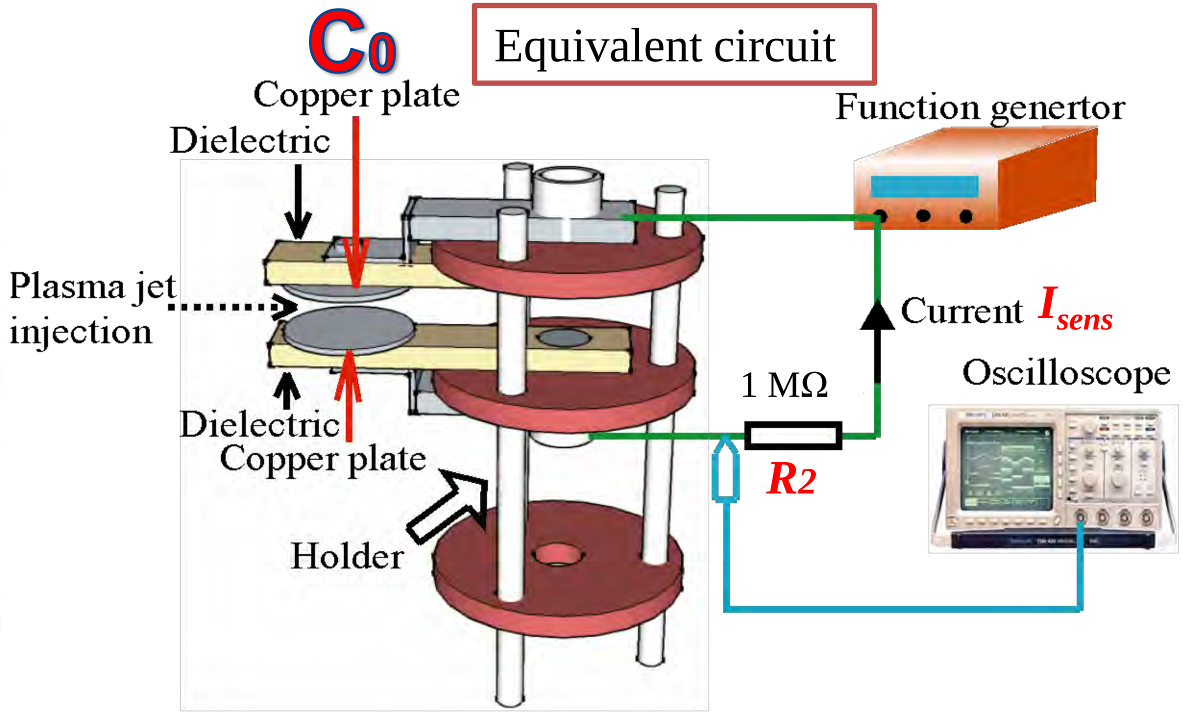
- Inner electrode
- Outer electrode
- MACOR tube
- MACOR disk (dielectric)

Impedance measure

Photograph



Equivalent circuit

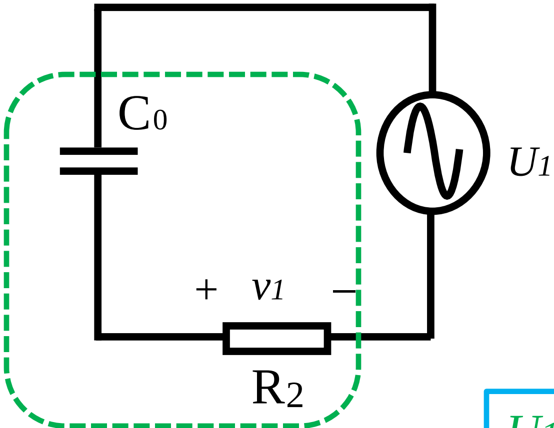


To avoid the errors from sheath effect, we measure the plasma plume impedance by:

1. **Function generator (Tektronix CFG250)** ➔ **Sinusoidal voltage signal (f ~ 175 kHz, $U_{p\text{-}p}$ ~ 10 V)**
2. **The flowing current I_{sens} is obtained by measuring the voltage across 1 MΩ resistor**
3. **The current variation before and after plasma injection can be used to calculate plasma plume impedance**

Calculation principle

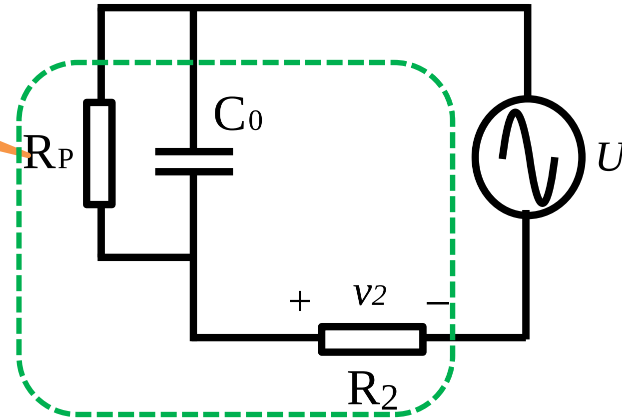
Without plasma injection



Impedance: Z_{off}

Plasma resistance?

With plasma injection



Impedance: Z_{on}

U1 U2: Output voltage from function generator

$$U_1 = \frac{v_1}{R_2} Z_{off} = \frac{v_1}{R_2}\sqrt{R_2^2 + \frac{1}{w^2 C_0^2}}$$

Ohm's law

$$U_2 = \frac{v_2}{R_2} Z_{on} = \frac{v_2}{R_2}\sqrt{R_2^2 + \frac{2R_2R_p + R_p^2}{R_p^2 w^2 C_0^2 + 1}}$$

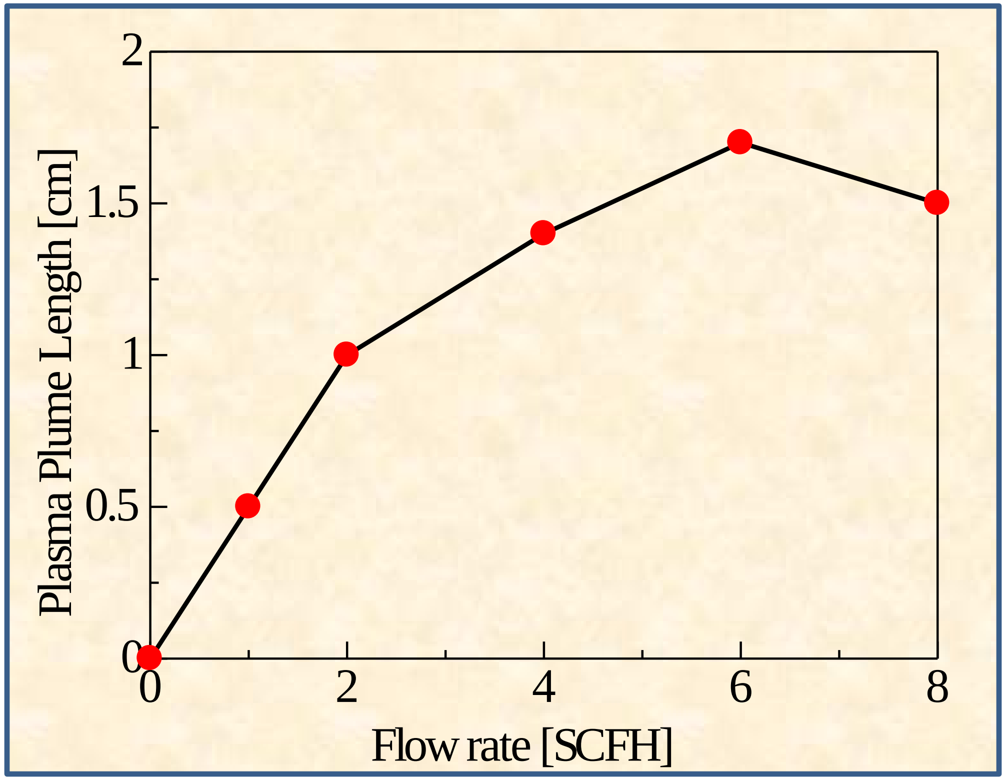
U₁ = U₂ ⇒

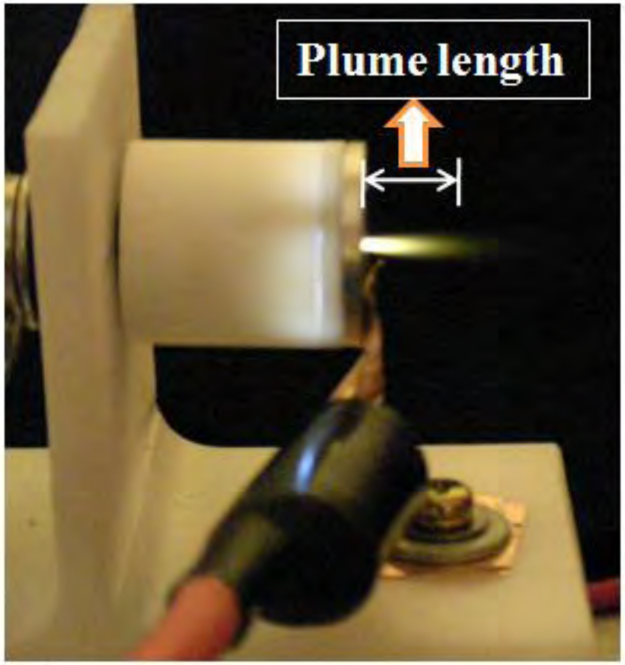
$$\underbrace{\left(1-\frac{v_1^2}{v_2^2}\right)\left(1+R_2^2w^2C_0^2\right)}_{a} R_p^2 + \underbrace{2R_2}_{b} R_p - \underbrace{\left[\left(\frac{v_1}{v_2}\right)^2\left(R_2^2+\frac{1}{w^2C_0^2}\right) - R_2^2\right]}_{c} = 0$$

$$R_p = \frac{-b+\sqrt{b^2-4ac}}{2a}$$

Result 1: Plume length

Dependence of visible jet length on N_2 flow rate. $V_{p\text{-}p} \sim 5\sqrt{2}$ kV





Reynolds number (*Re*) in the N_2 plasma jet device is estimated to be about 7.7 ×10^3 showing a turbulent flow

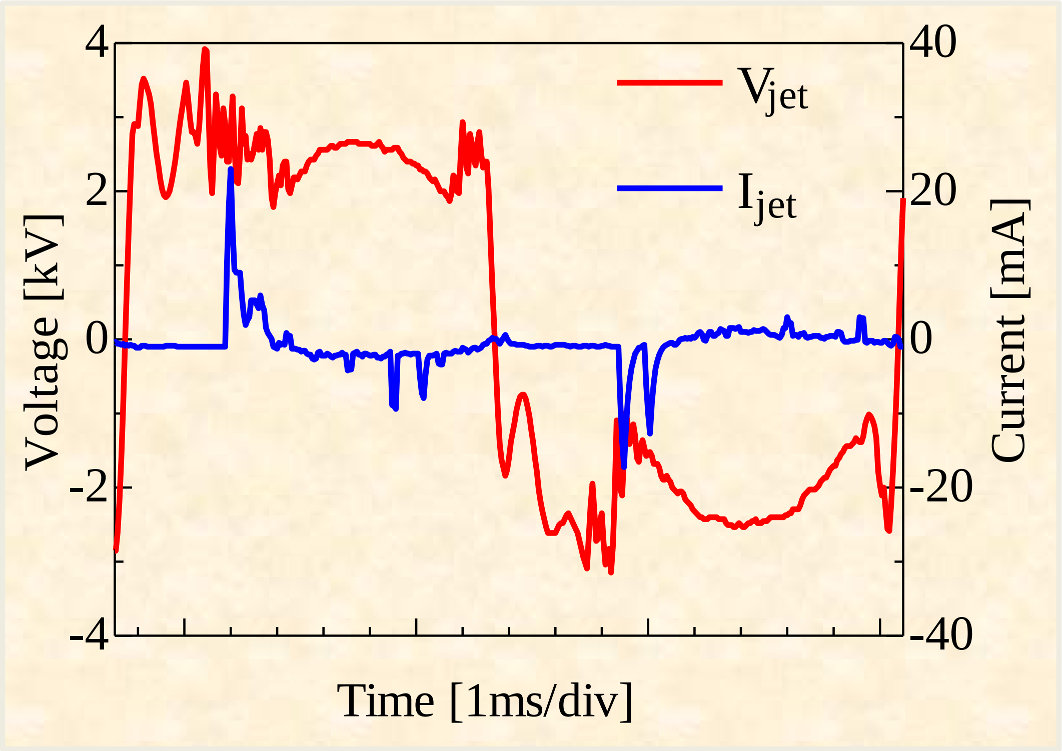
$$R_e = \frac{D \bullet v \bullet \rho}{\mu}$$

A maximum length of 1.7 cm is obtained with a flow rate of 6 SCFH (2.8 l/m)

Result 2: Waveforms

V-I waveforms of plasma jet: N_2 6 SCFH; *Vp-p* ~ 5√2 kV

Discharge Voltage *Vjet*



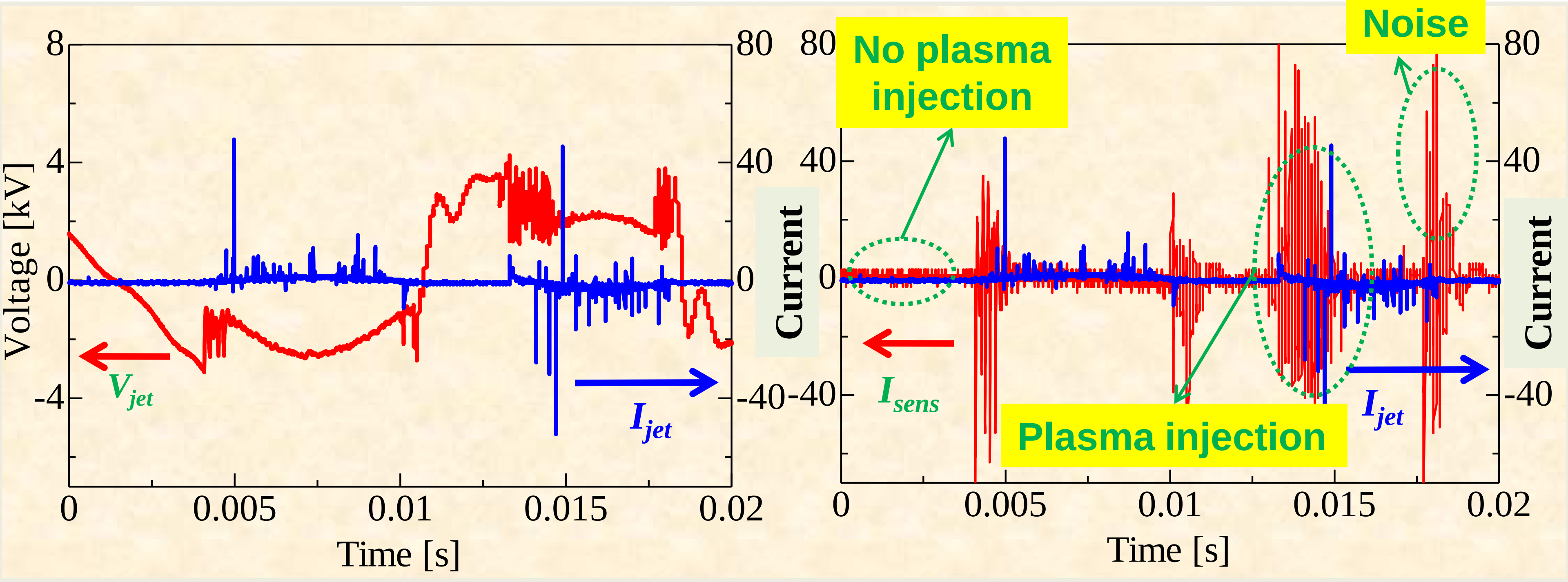
Discharge Current *Ijet*

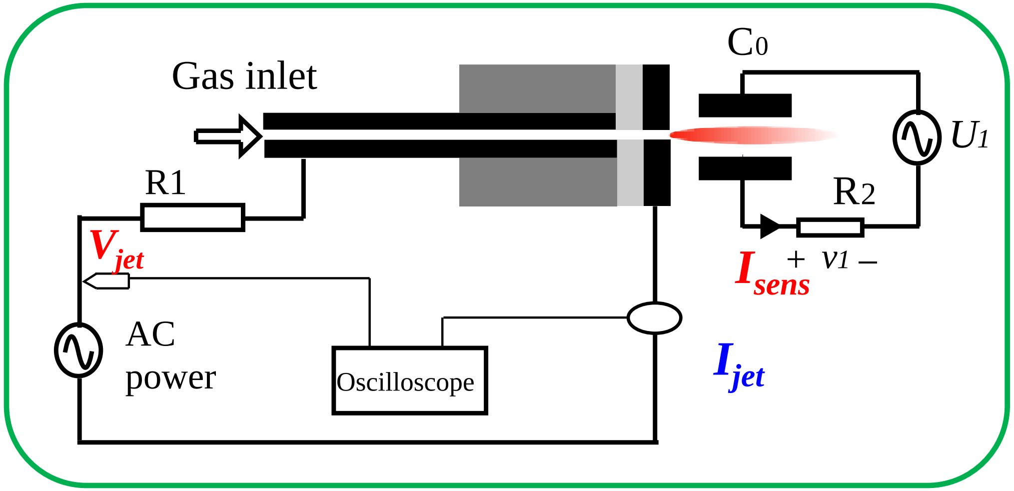
- **Like pin-to-plate discharge, the current spikes erratically appear on the temporal abscissa (axis of Time)**

- **The average duration of these current pulses is only about hundreds of ns**

Arc-similar discharge → High speed flowing gas cools the plasma jet

Result 3: Measurement





- ➢ ***I_{sens}*** **changes after plasma injection**
  ➔ *Possible to* calculate *R_p*
- ➢ **Obvious noise is seen**
  ➔ Need improving

Summary & Future work

Summary

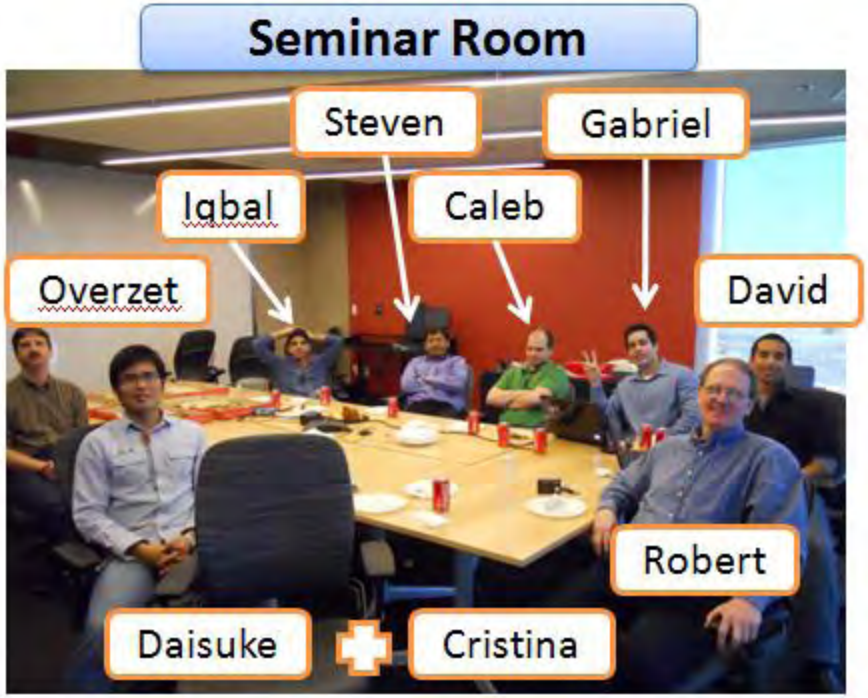
- **A plasma jet at atmospheric pressure using N_2 was designed and generated**
- **The plasma plume with a maximum length of ~ 2 cm can be produced by AC power for N_2**
- **A possible method was proposed and used to measure plasma impedance (because of short time, only the feasibility is confirmed)**

Next Work

1. **To generate air plasma jet: better transformer…**
2. **To investigate detailed characteristics: discharge power, temperature…**
3. **Improve the measurement**

Learn from UTD

Experience the different research atmosphere in UTD



Make the best of seminar:

1. **A place to learn, not just listen**
2. **Raise questions**
3. **Keep track of what the others do**

To communicate with Prof. effectively

1. **In UTD, > 2 times per week**
2. **How to discuss with Prof. effectively:**
   problem → your own solution→ bad result → talk to Prof. …

Thanks for attention!