

**Laboratory for Applied Sciences in  
Mechanics and Electrical Engineering **SIAME**  
and  
Solid State Pulsed Power group **S2P2****

Anton GUSEV



**Pulsed Power for Kicker Systems 2023 workshop**  
24th – 26th April, 2023  
Deutsches Elektronen-Synchrotron DESY  
Hamburg, Germany

# The **SIAME** Laboratory of the University of **Pau**



# SIAME Laboratory of the University of Pau

Complex and energetic flows (EE)

Equipe EE

Geo-materials and structures for  
civil engineering (GS)

Equipe GS



Laboratoire des **S**ciences pour l'**I**ngénieur  
Appliquées à la **M**écanique et au génie **É**lectrique

High Voltage Processes (PHT)

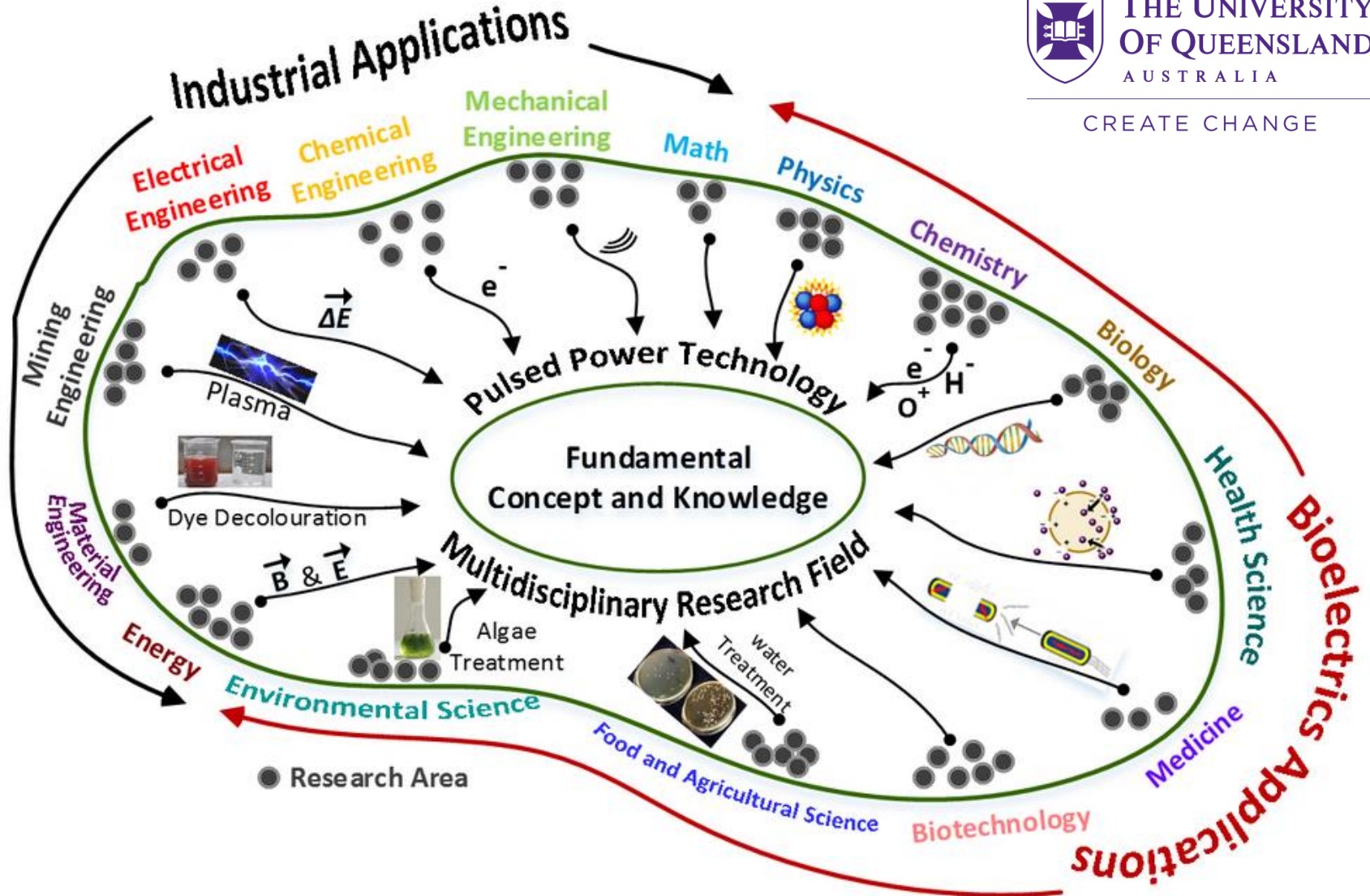
Equipe PHT

Wave / Structure Interaction (IVS)

Equipe IVS

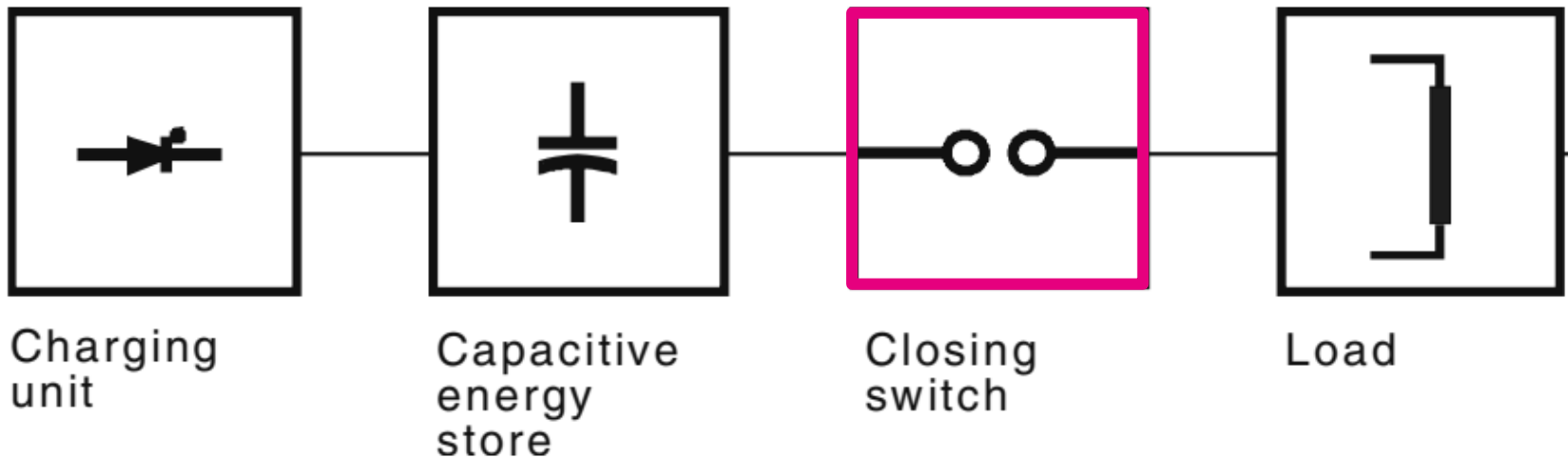
<https://siame.univ-pau.fr/en/home.html>

# Why Pulsed Power?



# What Pulsed Power is?

## Pulsed power



H. Bluhm, **Pulsed Power Systems**. Berlin/Heidelberg: Springer-Verlag, 2006.

# Why Solid State?

## Spark gap switch



VS

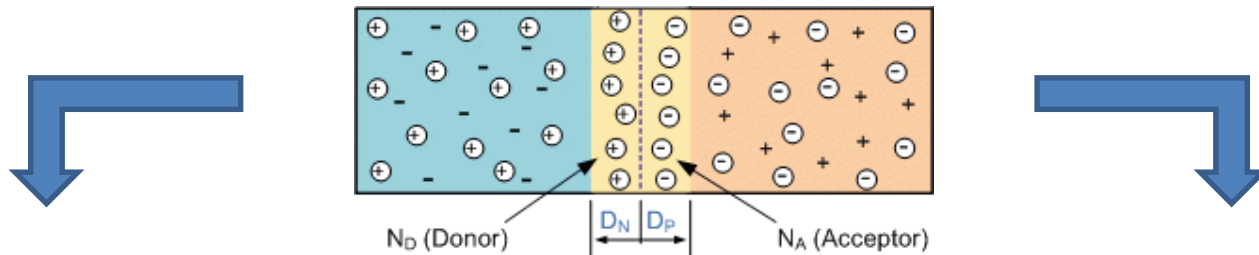
## Solid state switch



|                            | Spark gap | Solid state     |
|----------------------------|-----------|-----------------|
| Price                      | low       | high            |
| Manufacturing process      | easy      | doable          |
| Suitable for Pulsed Power? | yes       | today - yes!    |
| Pulse repetition frequency | low       | high            |
| Lifetime                   | low       | almost infinite |
| Industrial applications?   | no        | absolutely      |

# Scientific Background

## Semiconductors



Semiconductor **Opening**  
**Switch** (SOS technology)



Impact Ionization  
**Closing Switch**



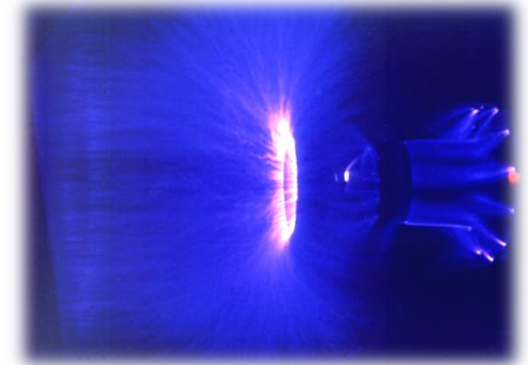


# SOS technology



## Distinctive features

- ✓ High PRF
- ✓ High stability of output pulses
- ✓ Long lifetime



## Fields of application

- ✓ Nanosecond electron accelerators
- ✓ X-ray apparatus
- ✓ High-power microwaves
- ✓ Nanosecond gas discharge

### Ultimate parameters of SOS generators

|   |                  |
|---|------------------|
| <b>Voltage</b>                          | <b>1 MV</b>      |
| <b>Current</b>                          | <b>14 kA</b>     |
| <b>Duration (FWHM)</b>                  | <b>10-100 ns</b> |
| <b>Pulse repetition frequency (PRF)</b> | <b>100 kHz</b>   |

S. N. Rukin, “**Pulsed power technology based on semiconductor opening switches: A review,**” Rev. Sci. Instrum., vol. 91, no. 1, p. 011501, Jan. 2020.





# Impact Ionization Switch



IEP UB RAS

## 1. Semiconductor Physics

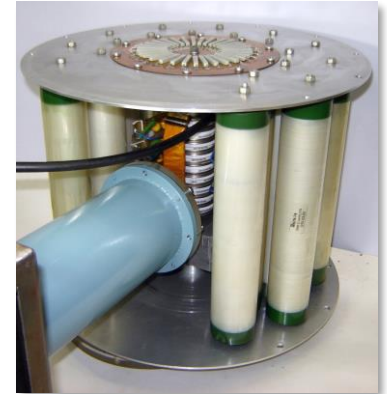
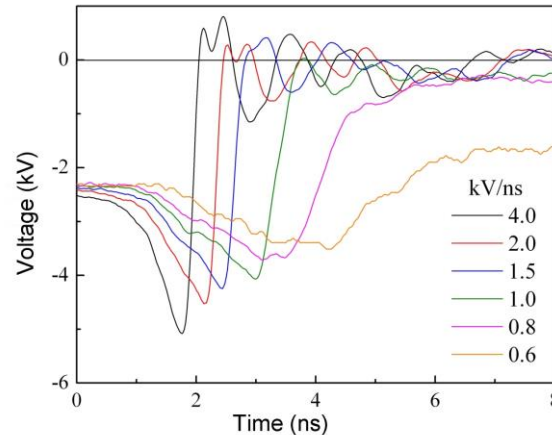
$t, S, di/dt \sim dU/dt, T$

## 2. Switch Prototypes

20 kV / 220 kA / 134 kA/ $\mu$ s

## 3. Implementation

Pulse generator  $\Rightarrow$   
efficiency  $\uparrow$   
mass, size and cost  $\downarrow$

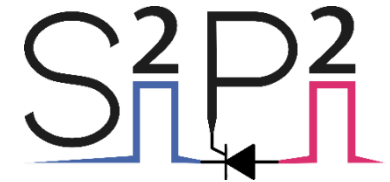


### Ultimate parameters of II switch

|                 |                 |
|-----------------|-----------------|
| Voltage         | 20 kV           |
| Current         | 220 kA          |
| Duration (FWHM) | 1-25 $\mu$ s    |
| $di/dt$         | 134 kA/ $\mu$ s |

A. I. Gusev, S. K. Lyubutin, S. N. Rukin, and S. N. Tsyranov, "Superfast Thyristor-Based Switches Operating in Impact-Ionization Wave Mode," IEEE Trans. Plasma Sci., vol. 44, no. 10, pp. 1888–1893, Oct. 2016.

# Structure of the S2P2 project



E2S UPPA Junior Chair  
Solid State Pulsed Power S2P2  
2020-2025

Opening Switch

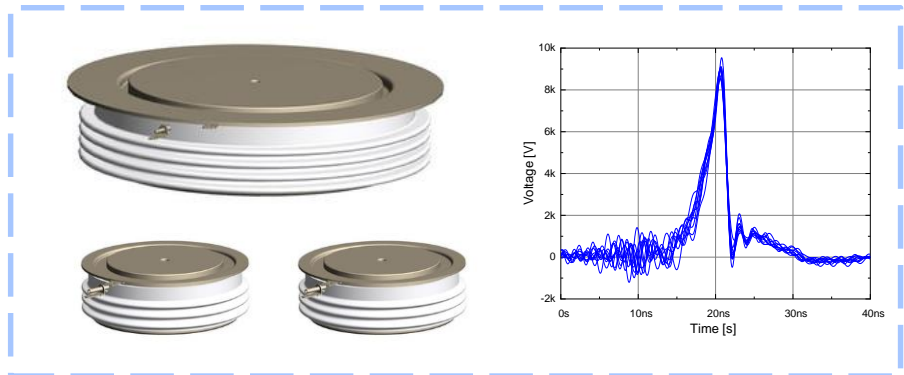
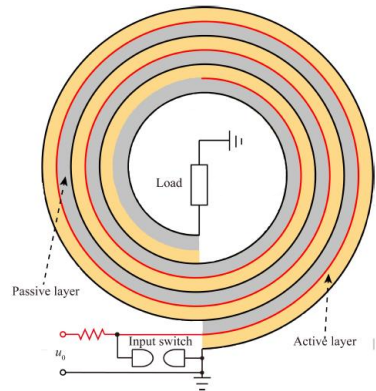
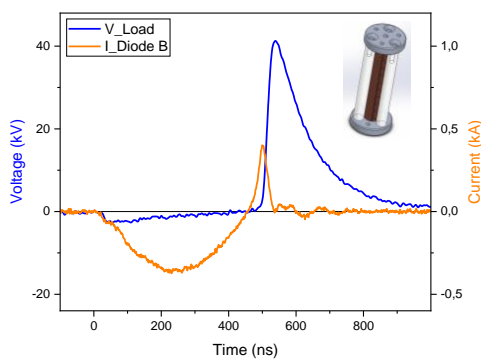
Closing Switch

PhD Student  
Rémi Degnon

Postdoc  
Ivan Lavrinovich

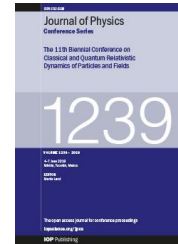
PhD Student  
Ejlal Shahriari

Postdoc  
Thomas Maysonnave



# Current outcomes of the **S2P2** project from 2020 to 2023

- **4 peer-reviewed publications**  
(+3 expected in 2023)



- **5 international conferences**  
(11 oral talk, 1 poster)

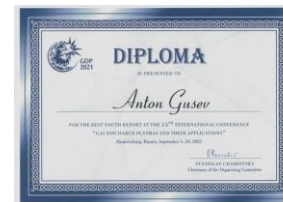


15<sup>th</sup> International Conference  
Gas Discharge Plasmas  
and Their Applications  
Ekaterinburg, Russia, 5-10 September 2021



9<sup>th</sup> Euro-Asian Pulsed Power Conference  
24<sup>th</sup> International Conference on High-Power Particle Beams

- **3 young researcher awards**



- **7 international workshops**

# Partners of the **S2P2** project

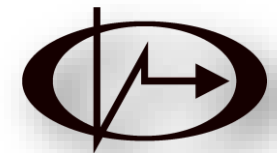
ITOPP  
ALCEN



Imperial College  
London

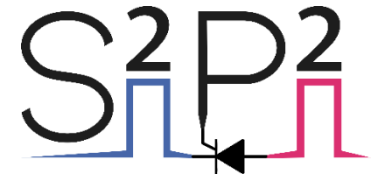


Loughborough  
University



IEP UB RAS





**Laboratory for Applied Sciences in  
Mechanics and Electrical Engineering **SIAME**  
and  
Solid State Pulsed Power group **S2P2****

Anton GUSEV



**Pulsed Power for Kicker Systems 2023 workshop**  
24th – 26th April, 2023  
Deutsches Elektronen-Synchrotron DESY  
Hamburg, Germany