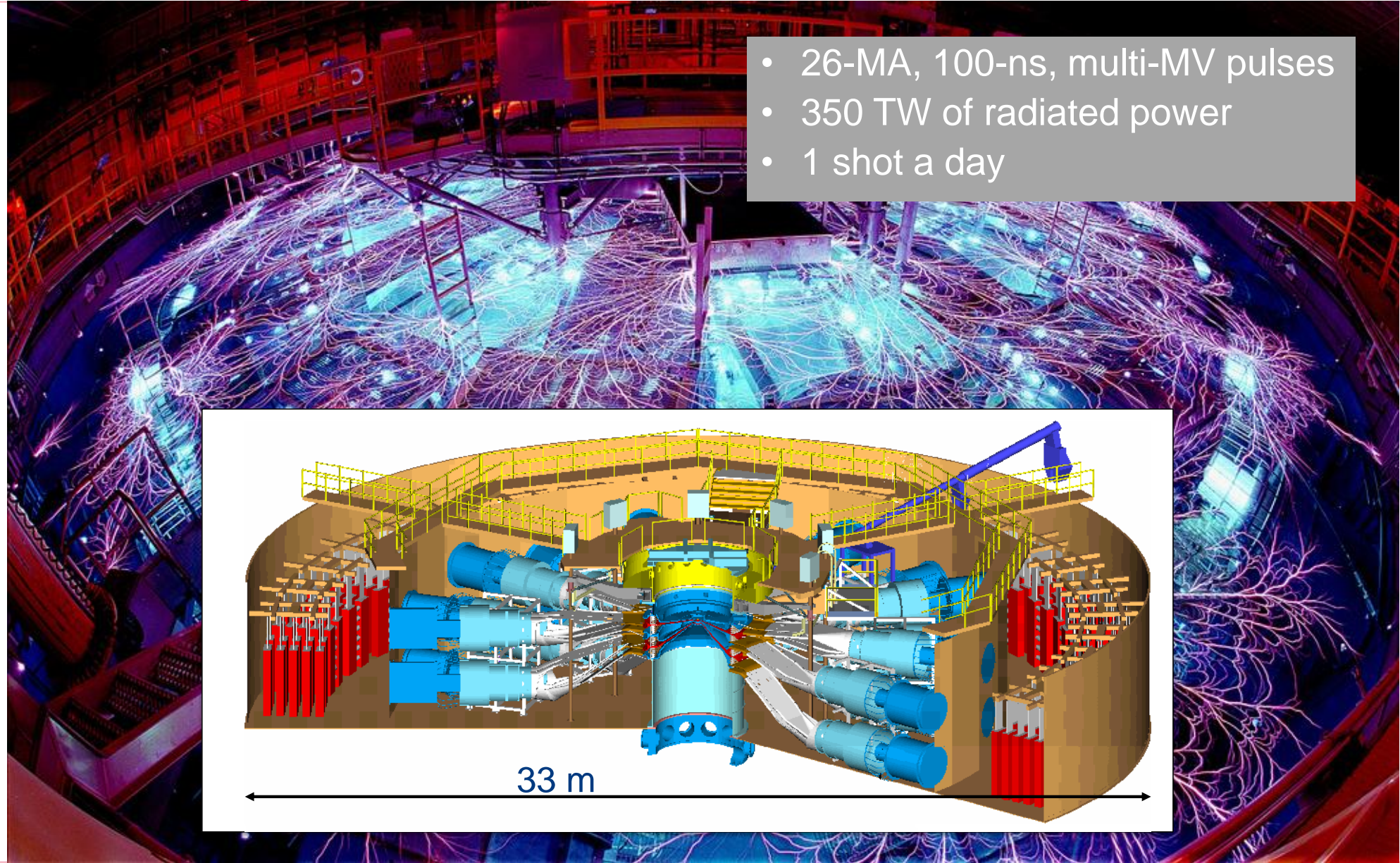
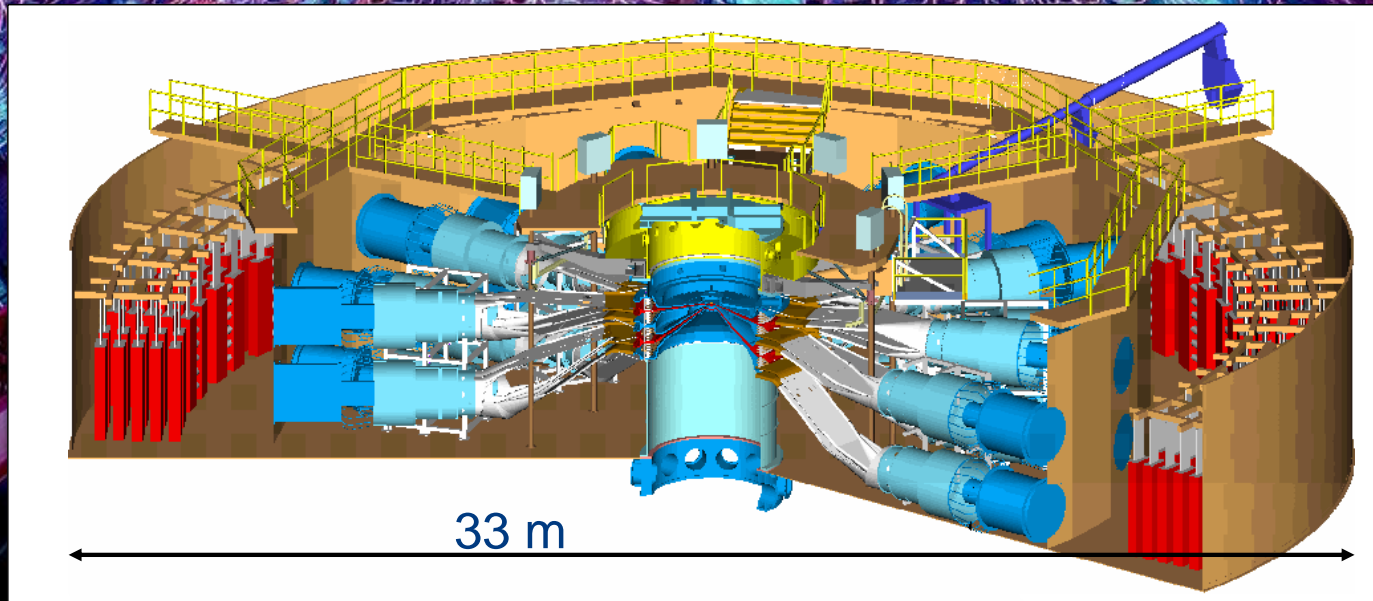




Gepulste hoogspanning – technieken en toepassingen

a.j.m.pemen@tue.nl

- 26-MA, 100-ns, multi-MV pulses
- 350 TW of radiated power
- 1 shot a day



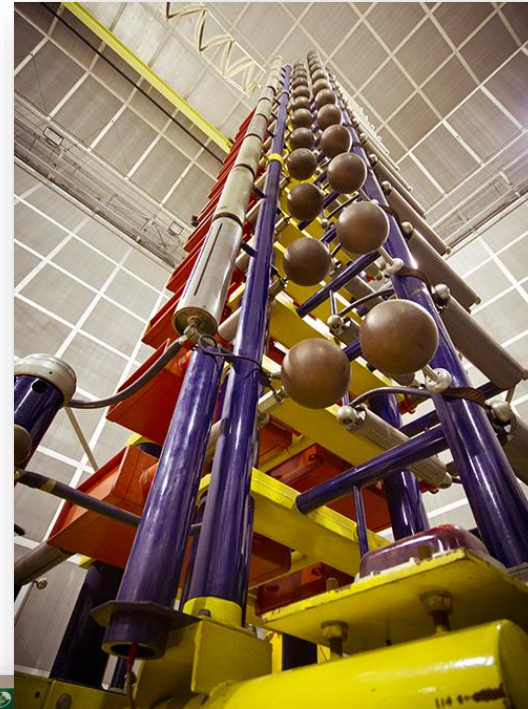
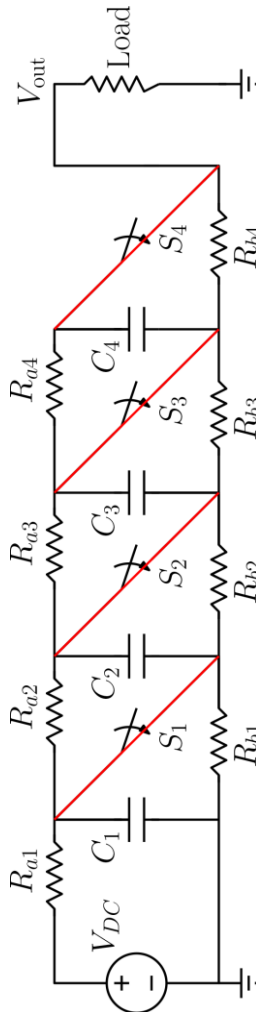
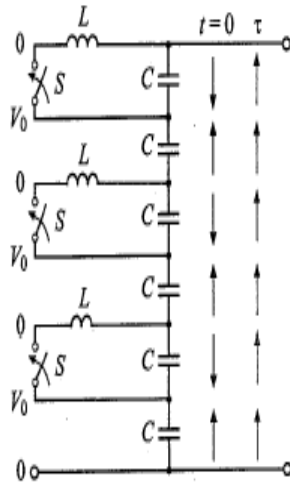
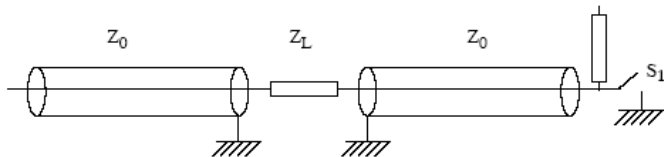
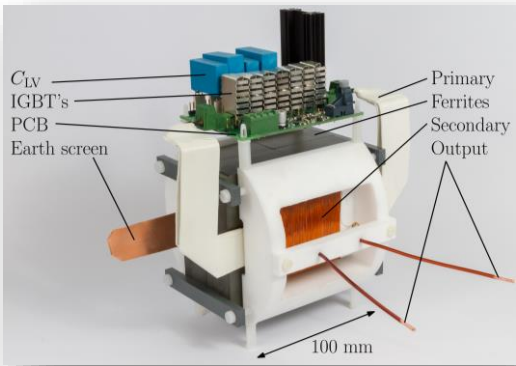
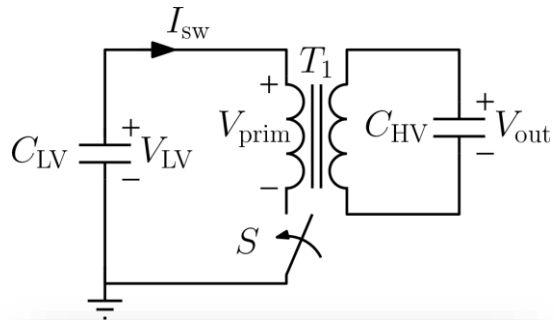
Example – plasma medicine

- 300 million people suffer from diabetes mellitus
- 45 million develop a foot ulcer, 1 million amputations per year
- Early treatment of patients may prevent 50-80 % of these amputations.

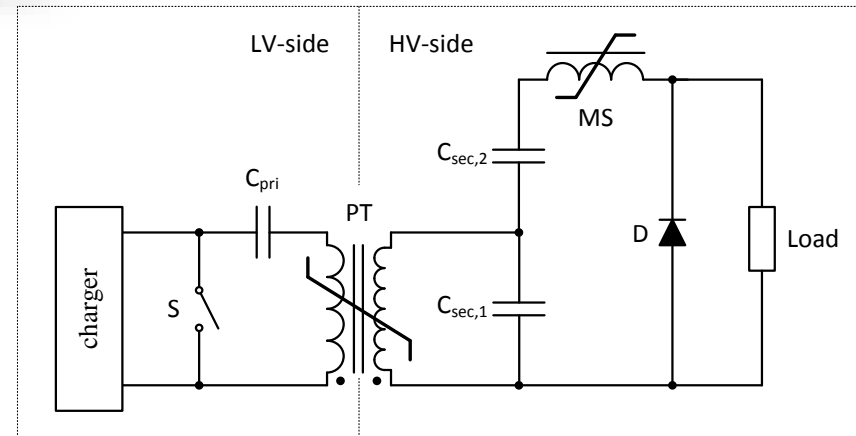
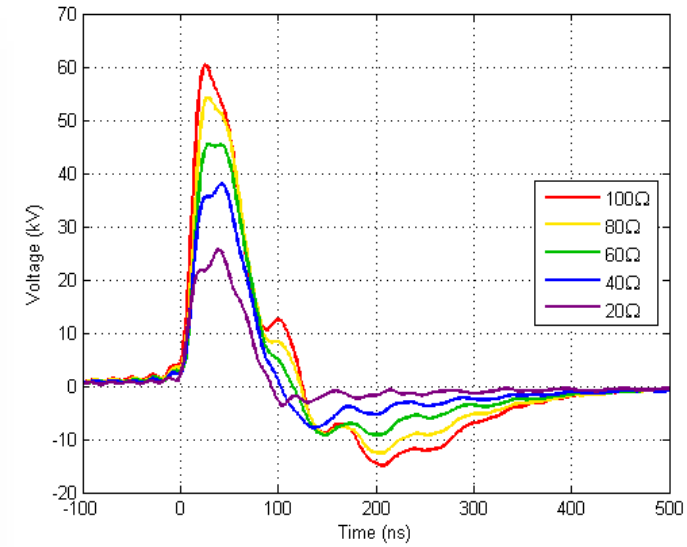
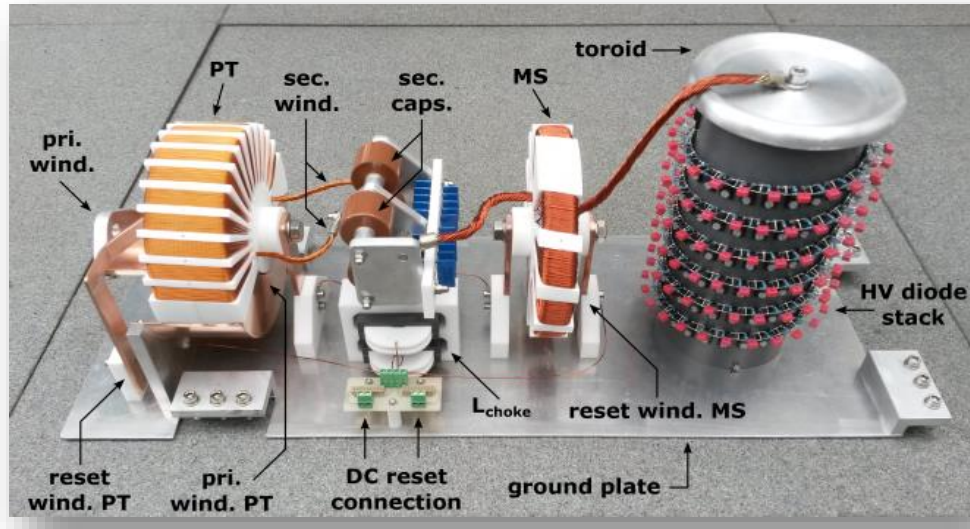
- Faster recovery of ulcerated skin and wounds
- Disinfection of (chronic) wounds
- Stimulates local blood circulation



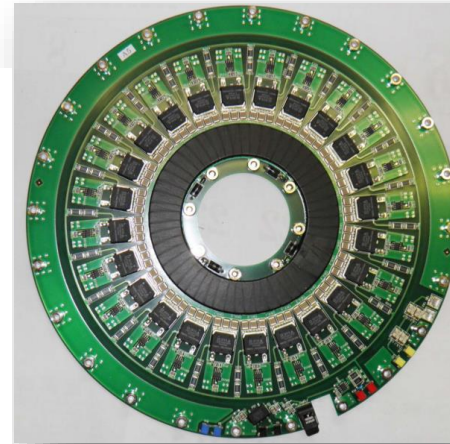
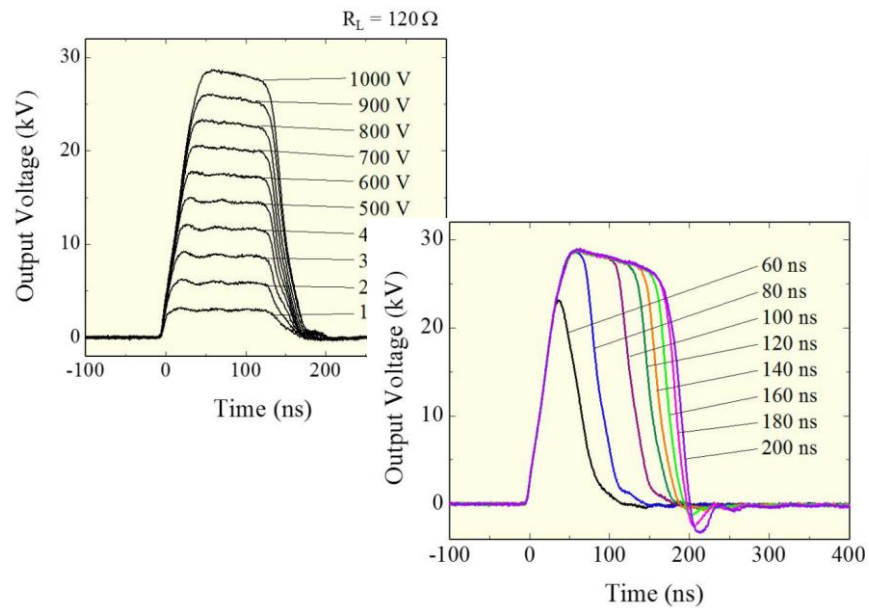
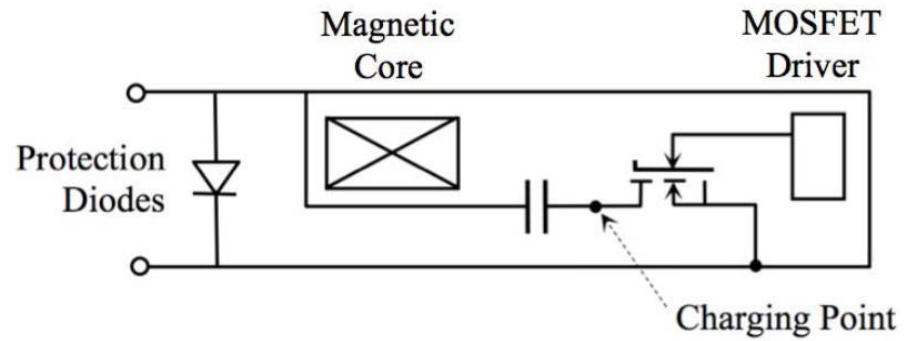
Some topologies...



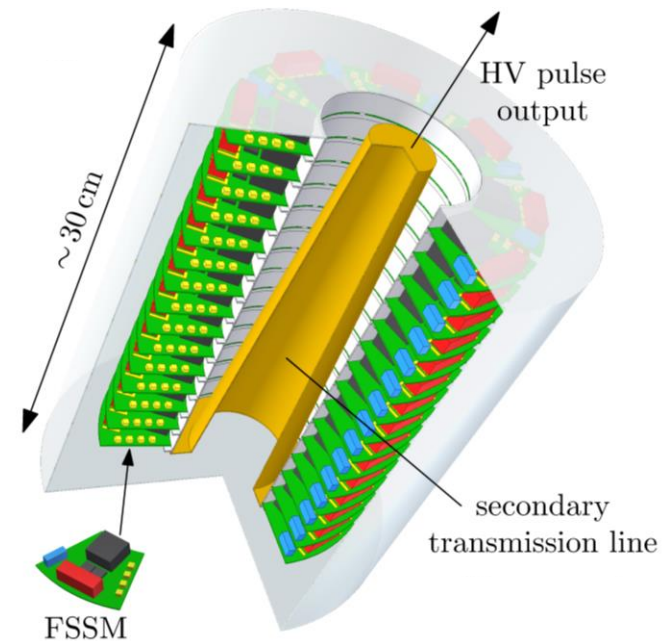
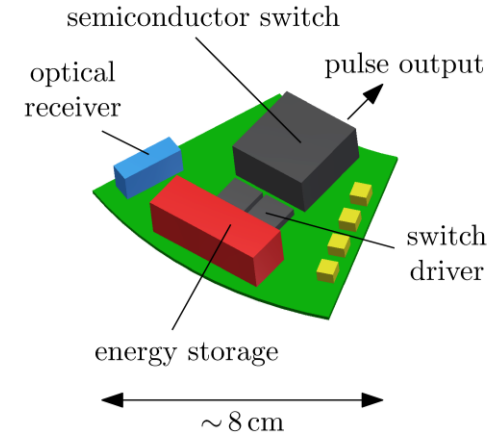
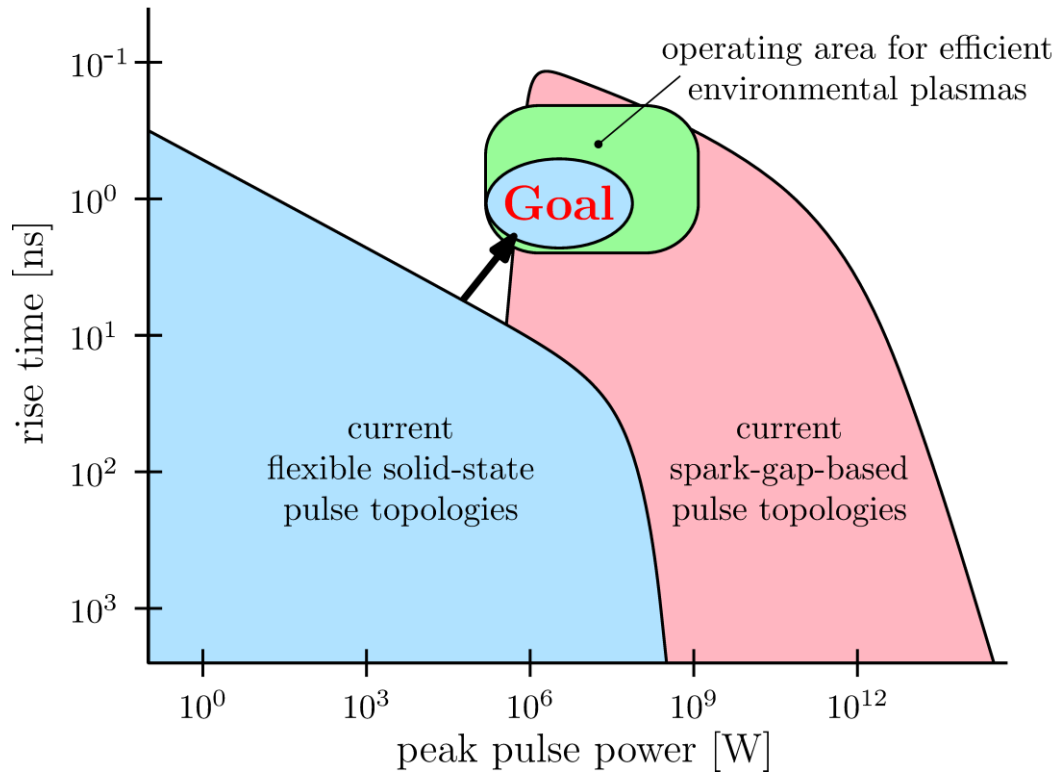
Magnetic pulse compression



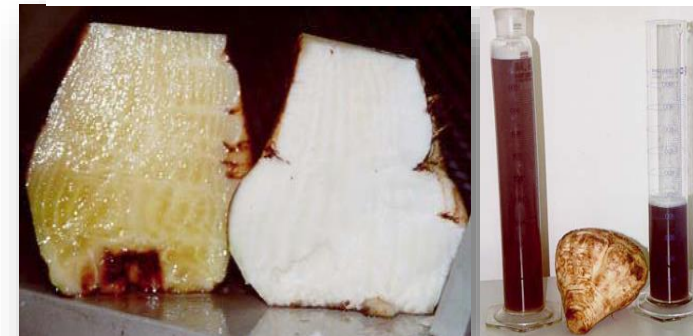
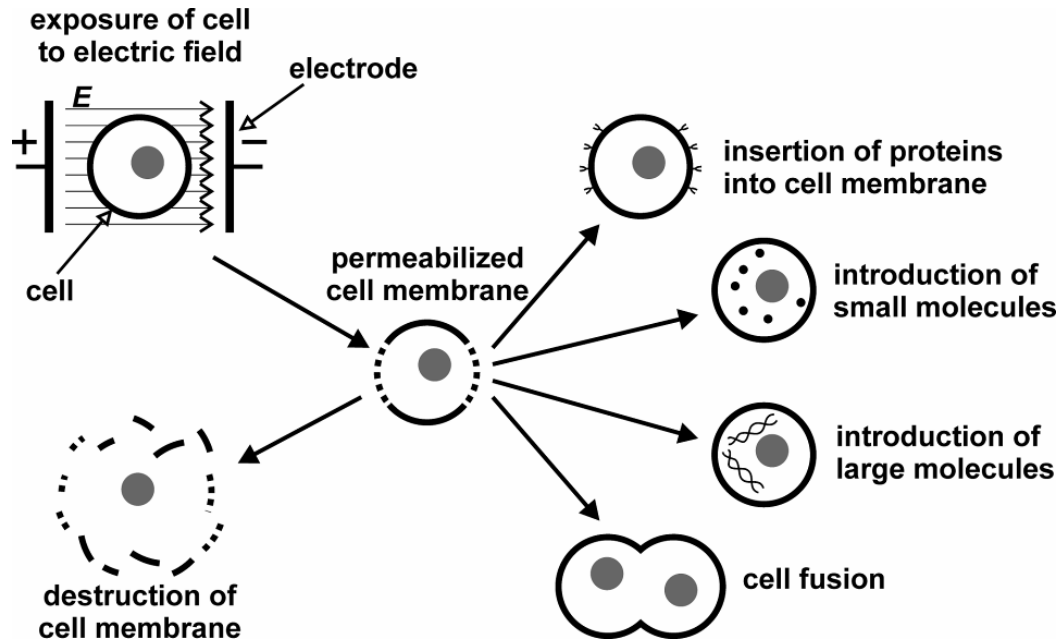
Linear transformer drivers (LTD's)



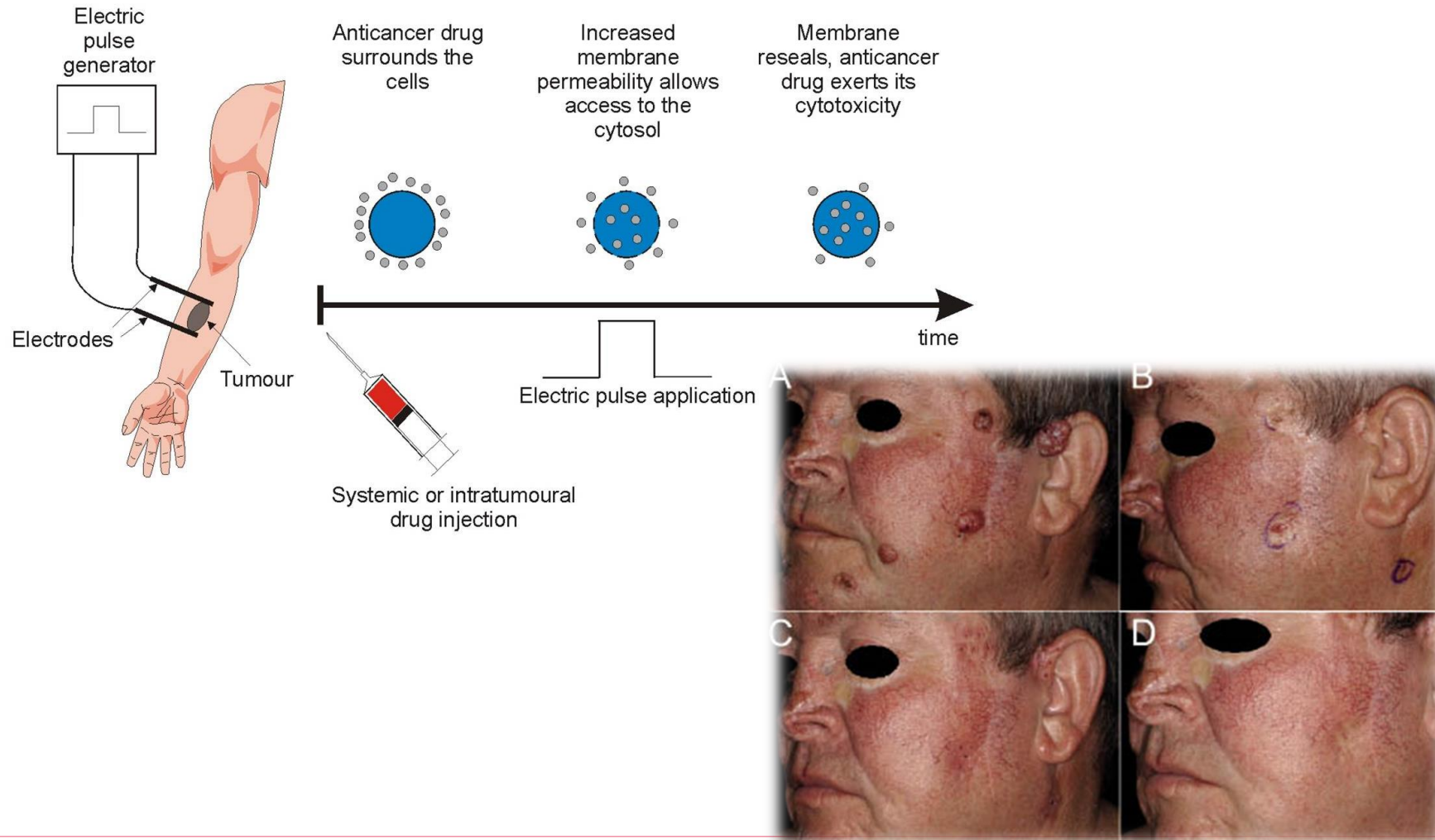
Pulsed power research @ TU/e



Electroporation



Electrochemotherapy



40% of world population has nothing to eat without fertilizer

- 2 % of global energy consumption
- 3.2 % of global CO₂ emission
- Energy cost 29 GJ/tN

- **Only air, water and (renewable) electricity**
- **Zero-emission of CO₂**
- **Energy cost 20-30 GJ/tN**
- **Decentral, on-site production**

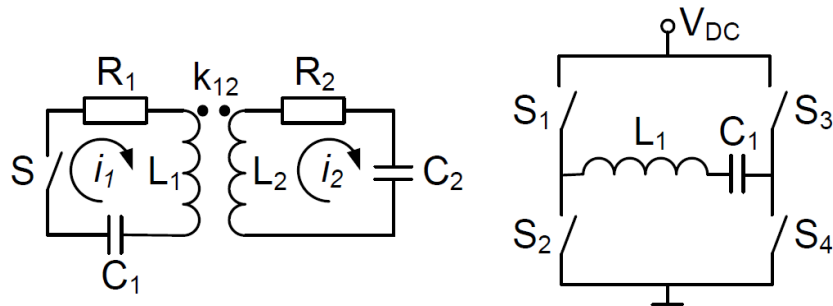
- **Crop protection + nutrient**



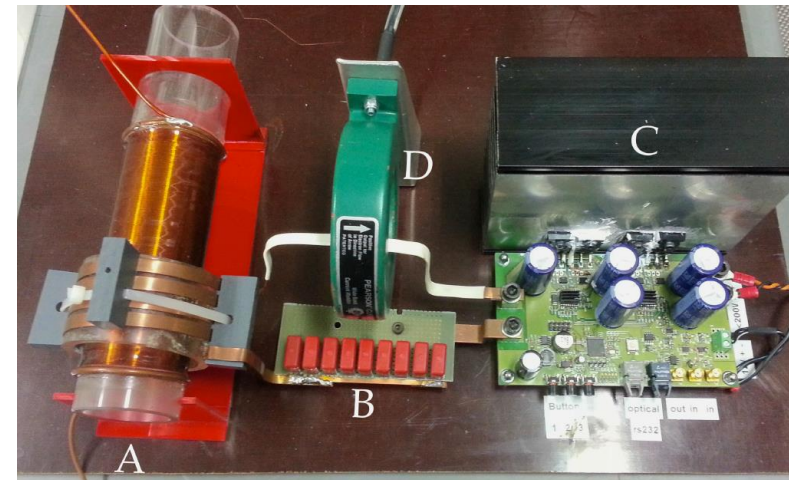
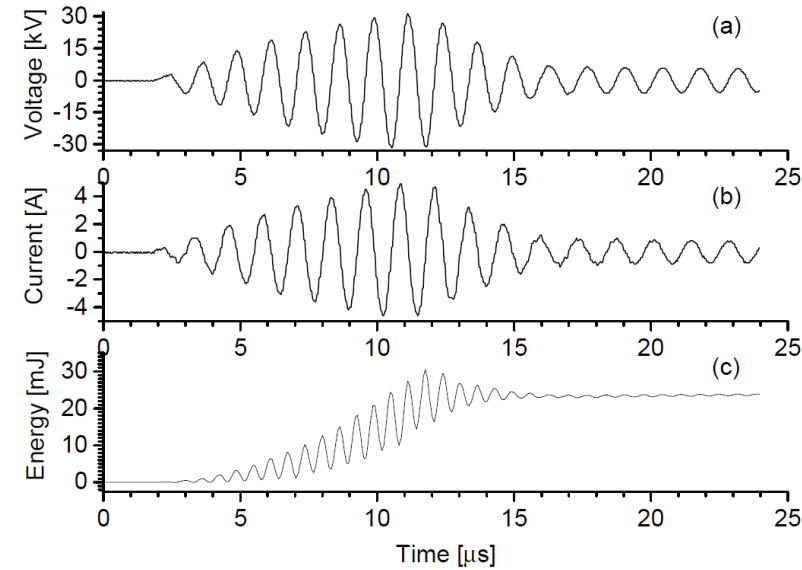
Plasma source for PAW production



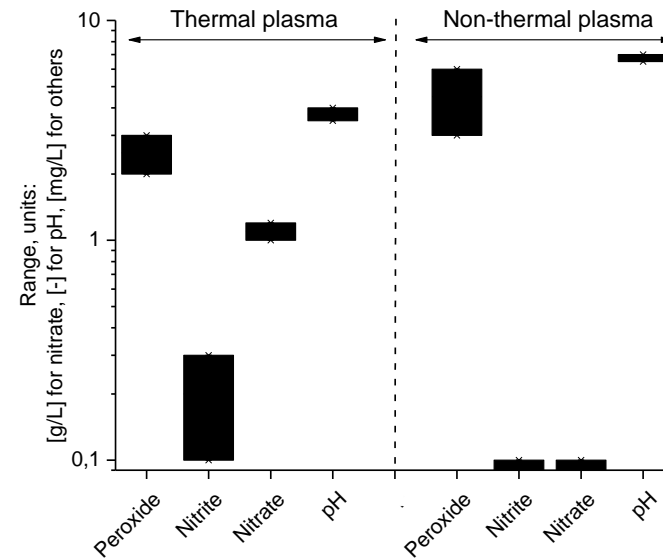
Power modulator for PAW



- Dual resonant circuit
- H-bridge to drive it
- MOSFET switches used
- “Lab” prototype built
- Controllability over waveform
- Thermal and non-thermal plasma possible!



Thermal vs. non-thermal plasma



- Thermal plasma: more RNS generation
 - More nitrate and nitrite
 - Fertilizer: competitive with Haber-Bosch process
- Non-thermal plasma: more ROS generation
 - More peroxide
 - Disinfecting properties

lean air

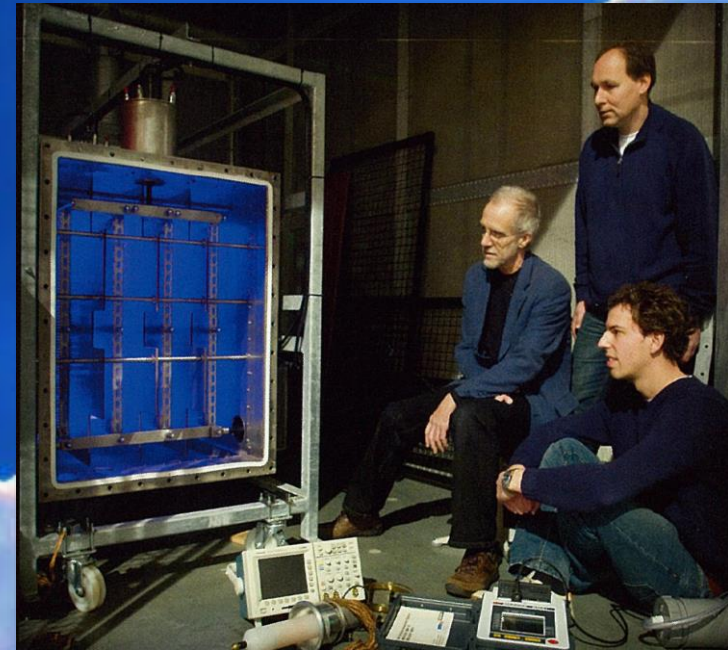
“2.000.000 young children die each year due to air pollution”

Unicef, 2012

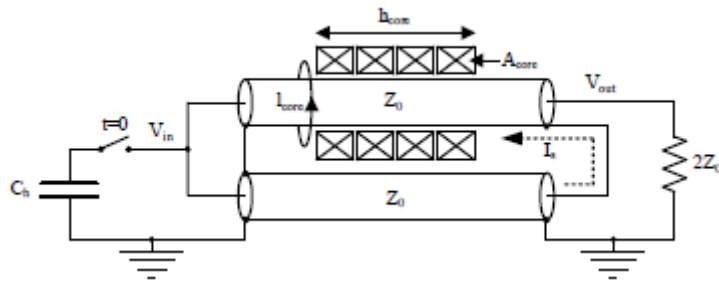
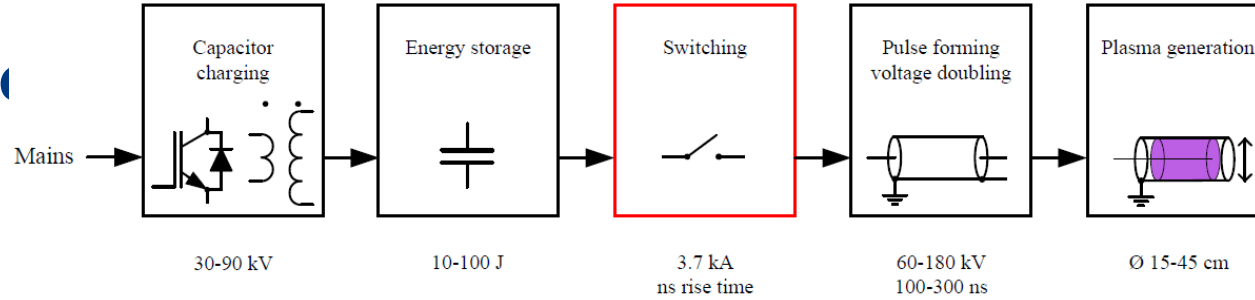
Environmental legislation becomes more stringent.

Need for new solutions to comply

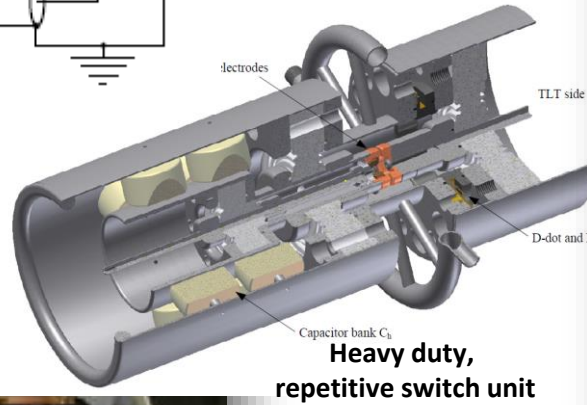
- **Low concentrations of pollutants.**
- **Multiple components (cocktails).**
- **Low cost and energy consumption.**
- **Wide range of target pollutants.**
- **Modular, scalable.**



Pulsed power



**Smart charger,
30 kV, 5 kHz, 20 kW, 30 μ s, 96 % efficient**



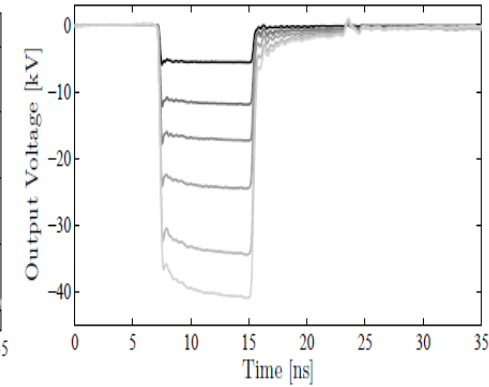
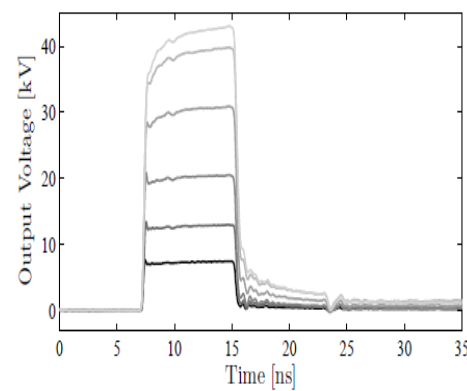
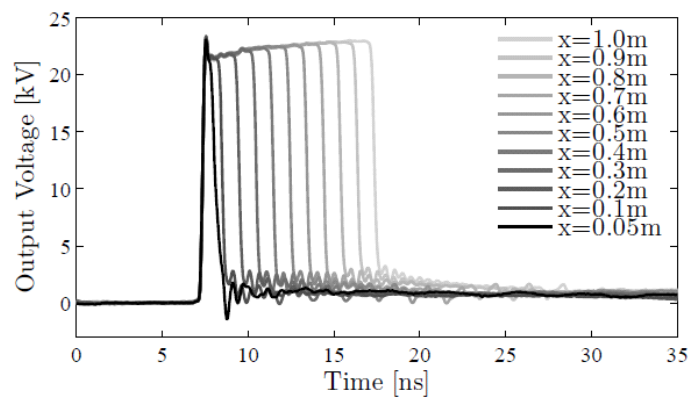
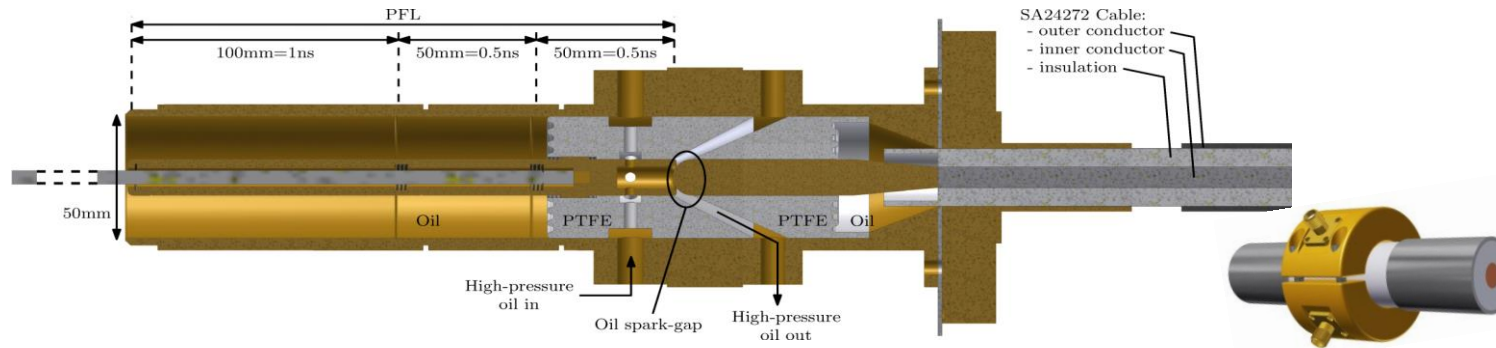
**Heavy duty,
repetitive switch unit**





Data on Performance	Pollutant concentration	Removal	Indicative power consumption (kW) at 1.000 m ³ /hour
VOC's :(toluene, TCA, Pentane, Ethylene, Furane, Terpens, Aromatic CH, Ketone, Aldehyde, Organic sulfur)	up to 500 ppm	80 -99 %	Toluene, 50 ppm, 60% removal @ 60 J/l - 17 kW
NOx	up to 60 ppm	up to 90%	10ppm 95% removal @ 8J/l – 2.2 kW
Odor	150.000-350.000 odor units / m ³ (NER L27 - NL specifications)	85-90 %	2 J/l – 0.6 kW
H2S	20 ppm	99 %	20 ppm 99% removal @ 9J/l – 2.5 kW
NH3	30 ppm	up to 90 %	10ppm 100% removal @ 5J/l – 1.4kW
fine dust	PM 1.0-2.5 up to 3 µg/m ³	80-95 %	90% removal @ 5 J/l – 1.4 kW
fine dust	PM .25-1 up to 250µg/m ³	50-65 %	60% removal @ 5 J/l – 1.4 kW
Tar	400 ppm	99%	> 150 J/l
traffic emissions	fine dust, HC and NOx	50-90 %	5 J/l – 1.4 kW

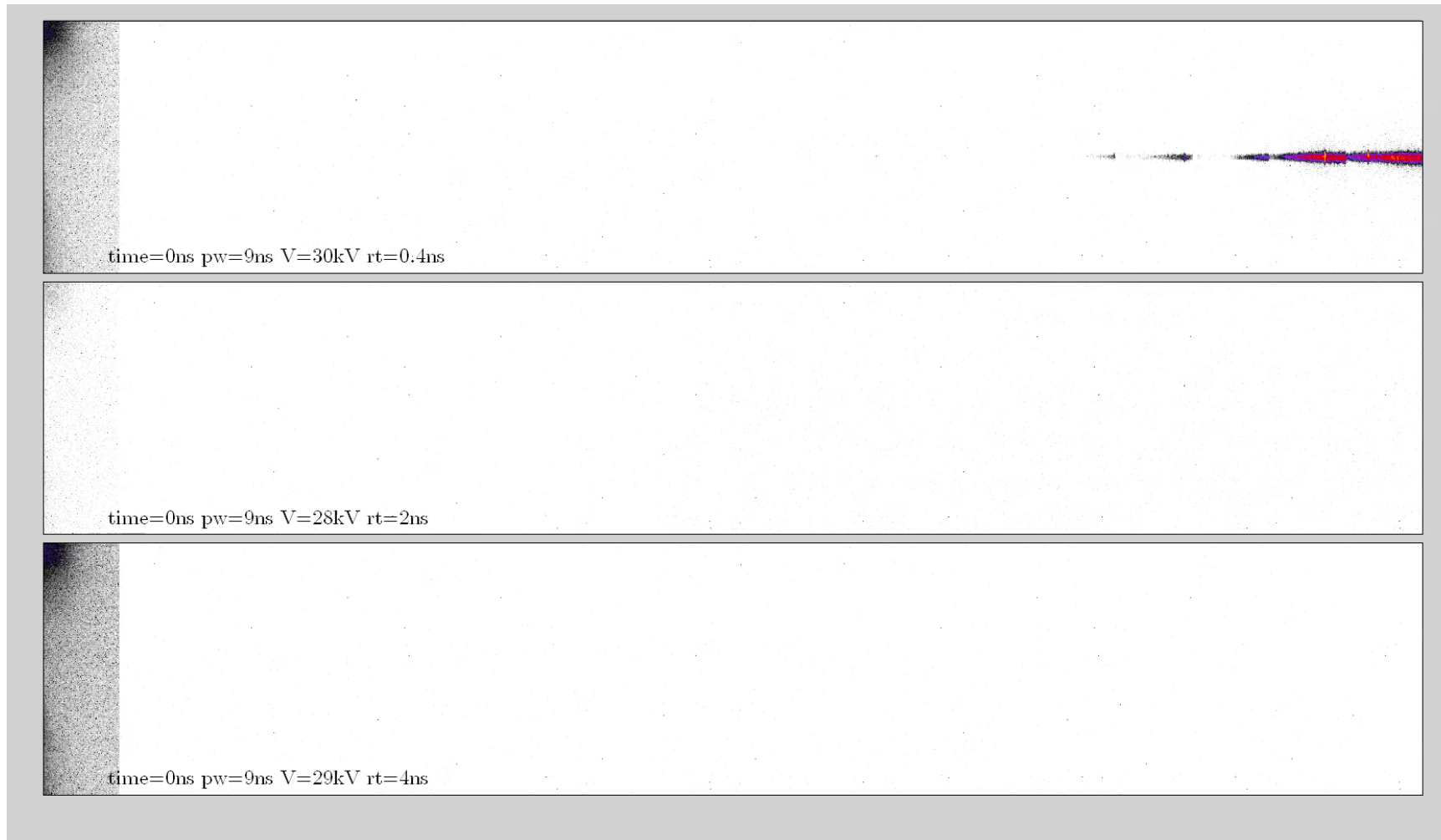
Adjustable (sub) ns pulsed power technology



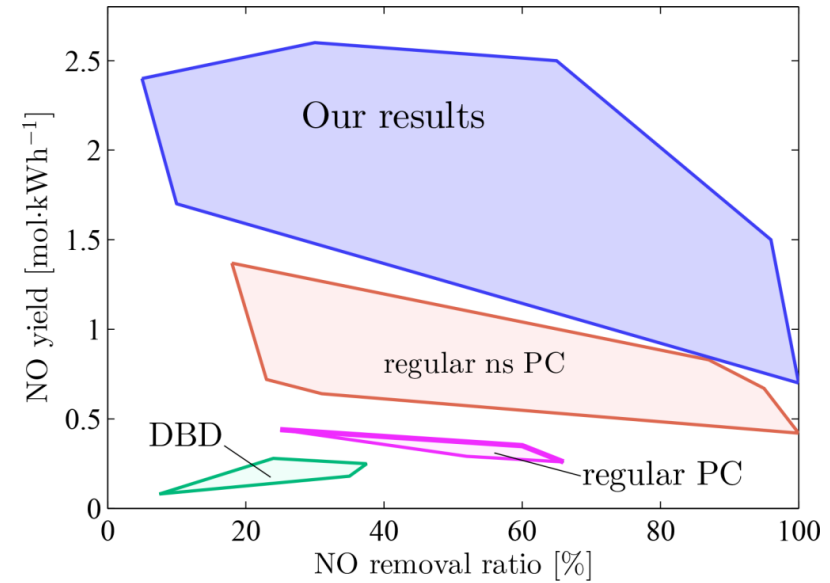
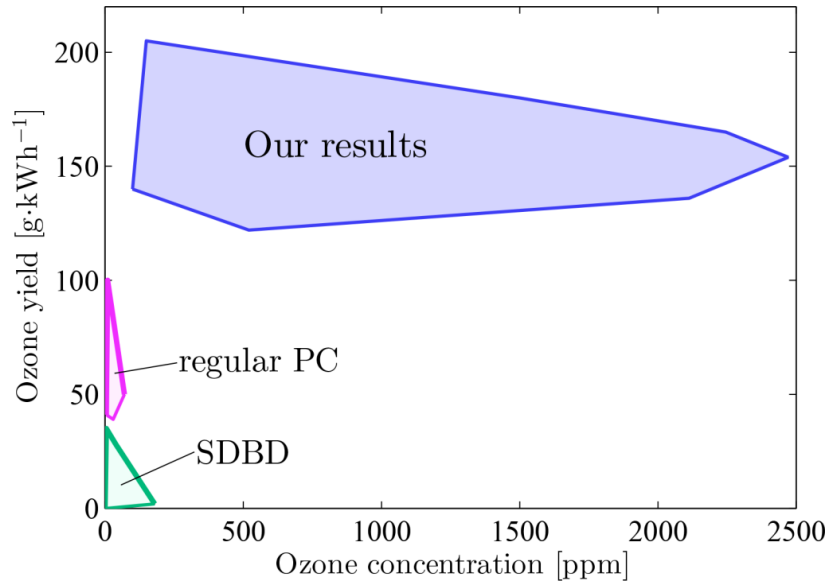
- Up to +/-60 kV, 0.5-10 ns duration, <200 ps rise time, 4 kHz rep.rate

Golden Eye

the world's fastest plasma

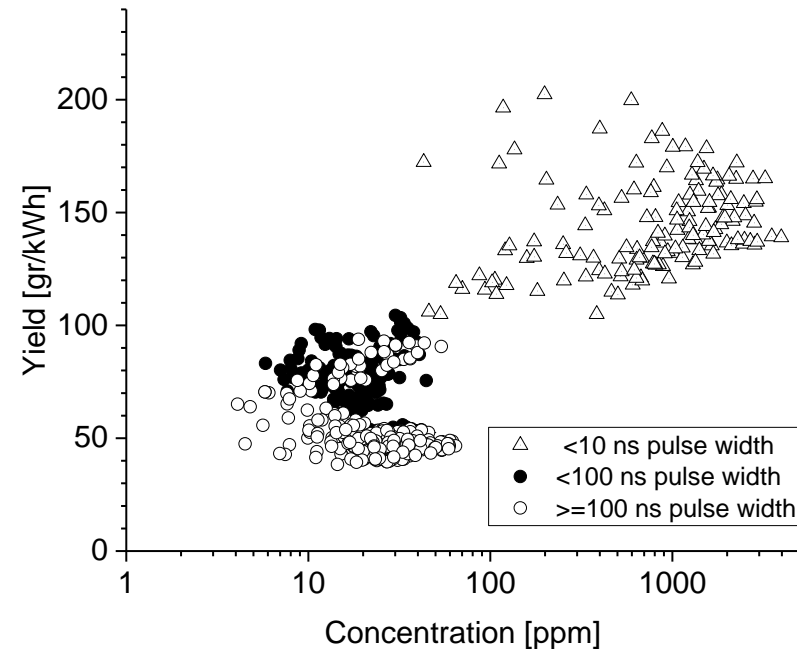


Record breaking plasma performance



Example – ozone

- Powerful oxidant, on-site production and use, no residues
- Purification of drinking water
 - Reduction of bacteria and pharmaceutical residues
 - Market 1.2 billion \$
 - 2.5 Mm³ daily, requires 45 MVA
- Potential energy reduction
50-75 % by applying
ns pulsed power and
transient plasma.



Outlook

- **Flexible** repetitive, nanosecond pulsed power technologies
- Solid state switch solutions
- Multi-level very fast pulsed power topologies
- **Adaptive** pulsed power techniques

- **World record** breaking plasma performance
 - Air and water purification
 - Sustainable agriculture
 - Plasma medicine

- Acknowledgements: Tom Huiskamp, Wilfred Hoeben, Bert van Heesch, Frank Beckers, Gerrit Kroesen, Sander Nijdam, Ute Ebert, Polo van Ooij, Paul Leenders, Bas Zeper, Pauline Smits

