Analoge & Digitale Leistungselektronik GmbH

- DC-Power Supply HX300/800
  - Arc-Management with resonant circuit
- Unipolar Pulse Generator SD300 / SD301
  - Active Arc-Management
- Bipolar Pulse Generator SB300
  - General Concept
- Arc-Measurement
  - Important Arc Parameters
- Comparison ADL SB300 – Competition

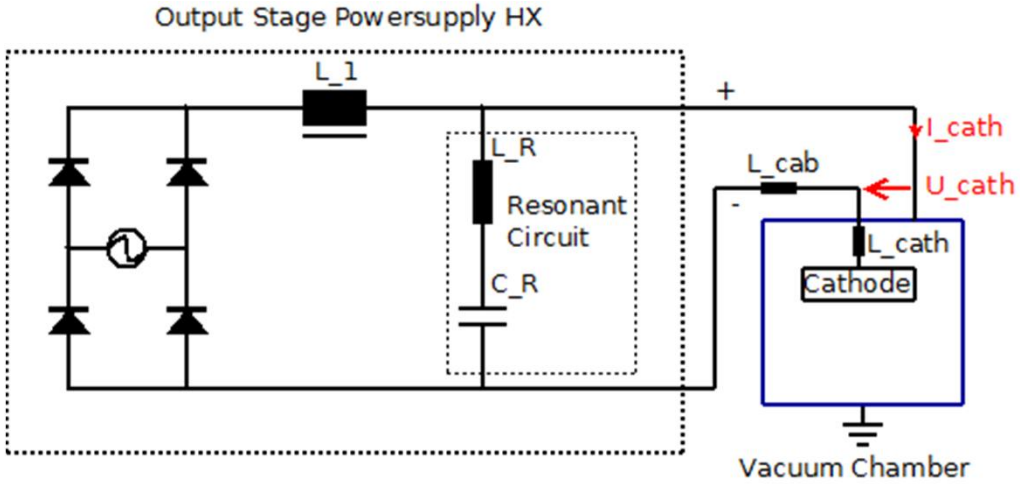

Figure 1: Output Stage

- Inductance L_1 smoothens rectified output current and prevents rapid current increase during arcing
- Inductance L_R and capacitor C_R form the resonant circuit
- L_cab represents cable inductance
- L_cath represents inductance of vacuum chamber

Arcing with HX 300/800 II

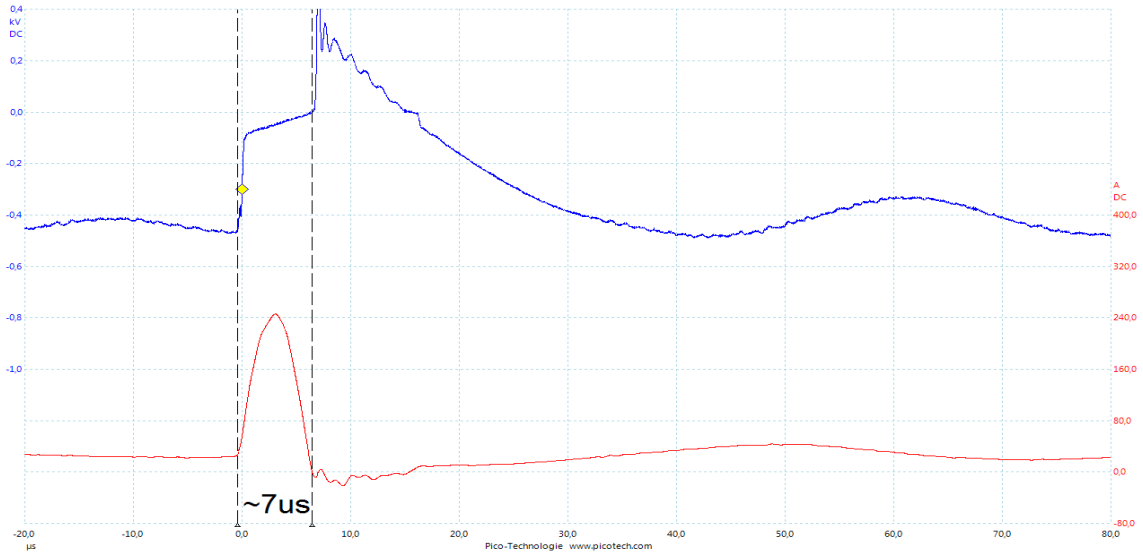

Figure 2:Arc event at HX output
- Voltage - Current

- Arc happens at t = 0, voltage drops rapidly and current increases
- The arc stimulates the resonant circuit to self-oscillation
- The oscillation leads to a reverse current, quenching the arc at t = 7 µs
- Most arcs can be quenched by resonant circuit
- No power shut down of power supply necessary
- Plasma ignited again after voltage dropped

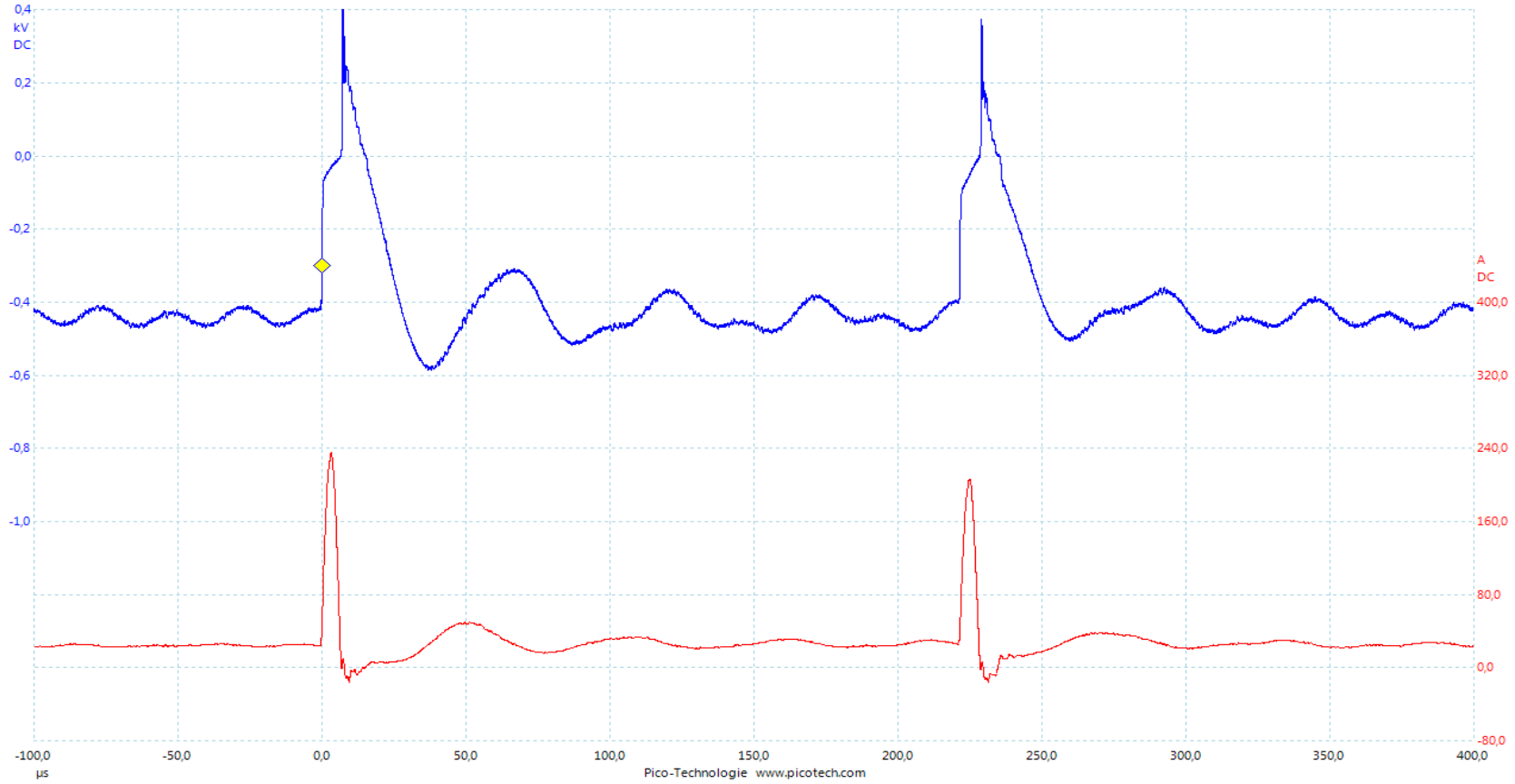

Figure 3:Two arcs in series on larger time scale
- Voltage - Current

Arcing with HX 300/800 IV

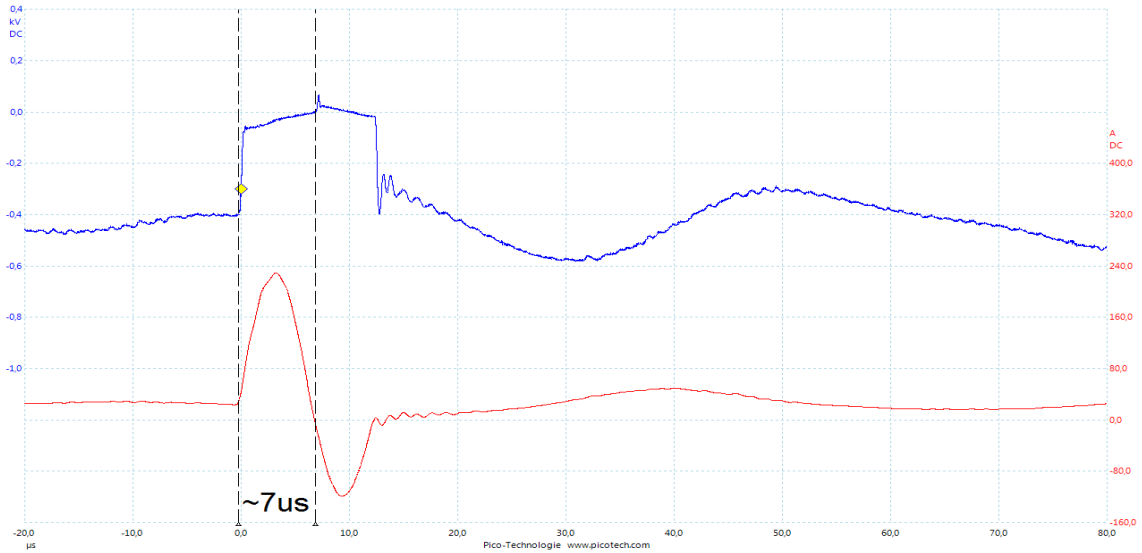

Figure 4: Arc Event with Cathode-Clamp Diode
- Voltage - Current

- Cathode-Clamp diode connected in parallel to the output of HX unit
- Arc happens at t = 0, voltage drops rapidly and current increases
- No reverse voltage possible, but full reverse current through diode
- Reverse current runs from t = 7 µs up to t = 12 µs
- Faster ignition of plasma because of no voltage reversal

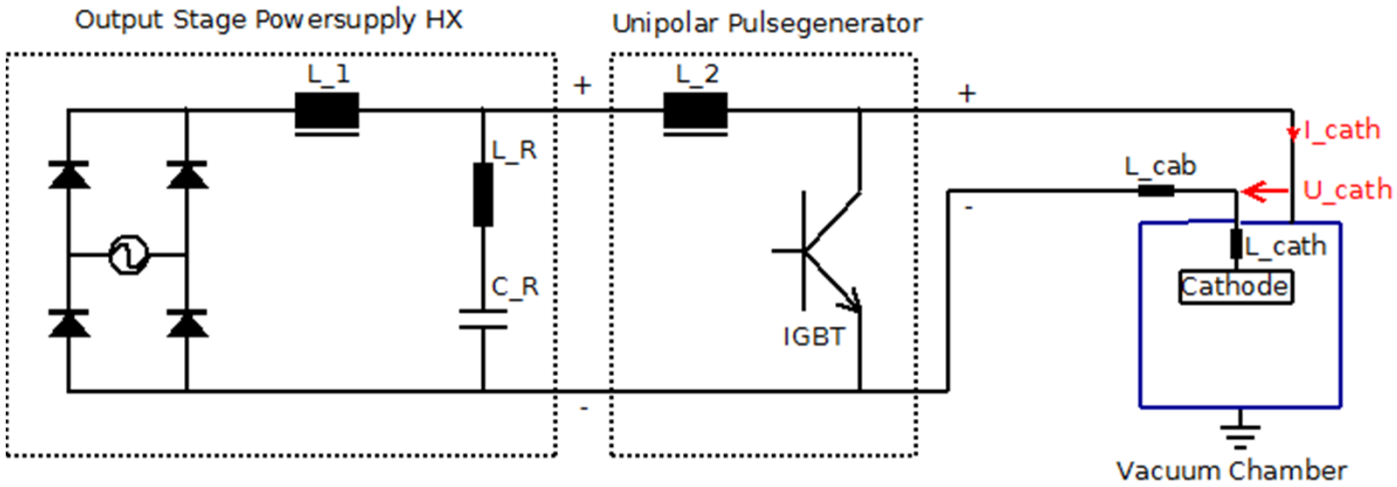

Figure 5: Unipolar Pulse Generator connected between HX and Vacuum Chamber

- Resonant circuit of HX is blocked by large inductance L_2 of pulse generator
- ONLY arc management of pulse generator is active
- Switching IGBT directly at the output of the pulse generator unit
- Current sourcing pulse unit principle
- Active arc handling, switch off with IGBT during arcing

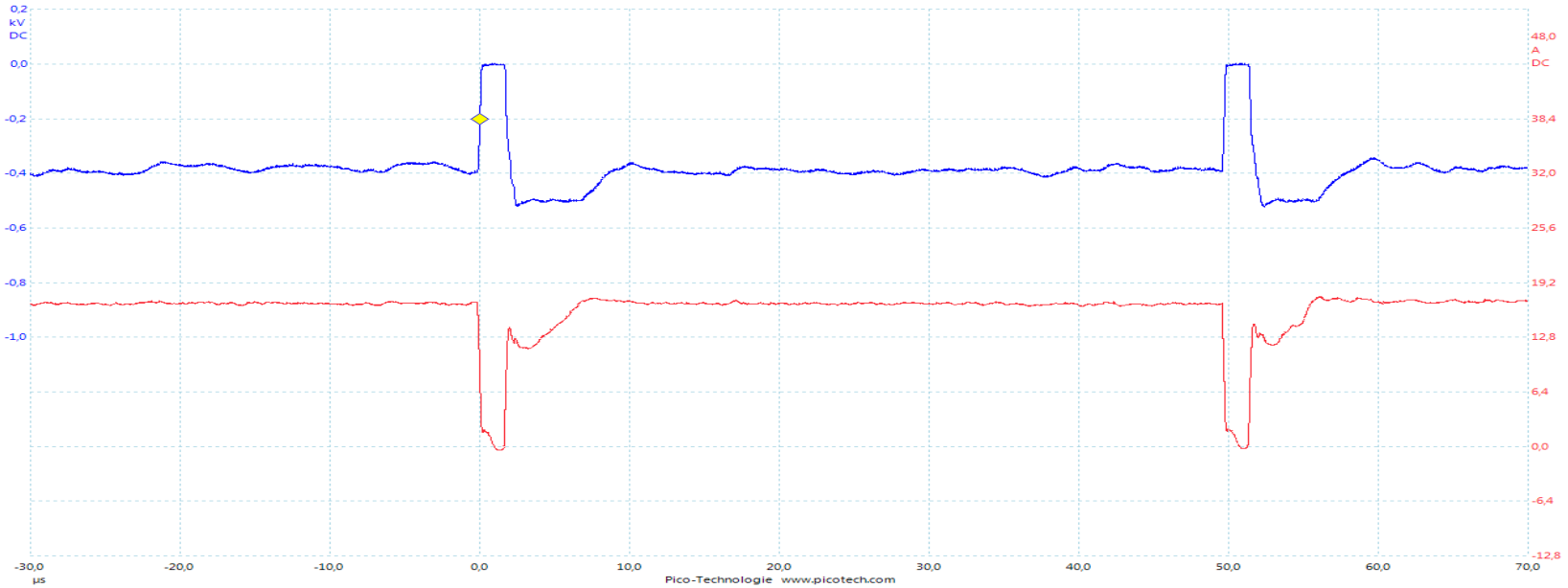

Figure 6:Voltage and Current waveform

- Voltage - Current

- Default setting 20 kHz with 48 µs On-time and 2 µs Off-time
- At t = 0 pulse generator shortens the output for 2 µs Off-time
- After Off-time the IGBT opens again

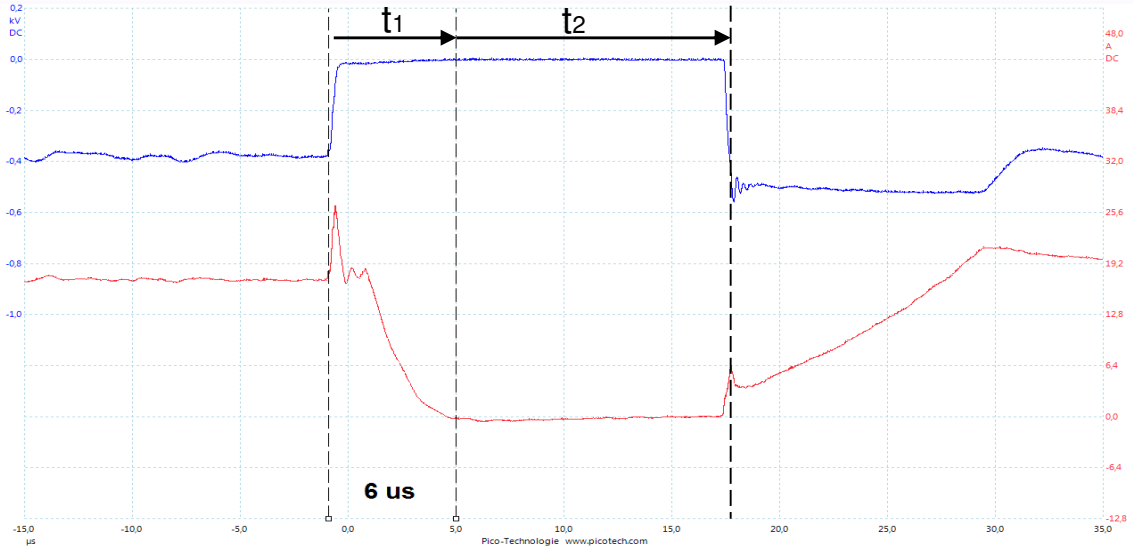

Figure 7: Voltage and Current waveform during arc event

- Voltage - Current

t_1 – variable, depending on current and cable / cathode inductance

t_2 – Pause time variable, automatically adjusted

- At t = 0 an arc event occurs
- The cathode current increases rapidly
- Maximum 1.5 µs after arc occurs the pulse generator shuts down
- Cathode current decreases and arc is quenched after 6 µs in this case
- The pulse generator restarts after additional 13 µs in this specific case

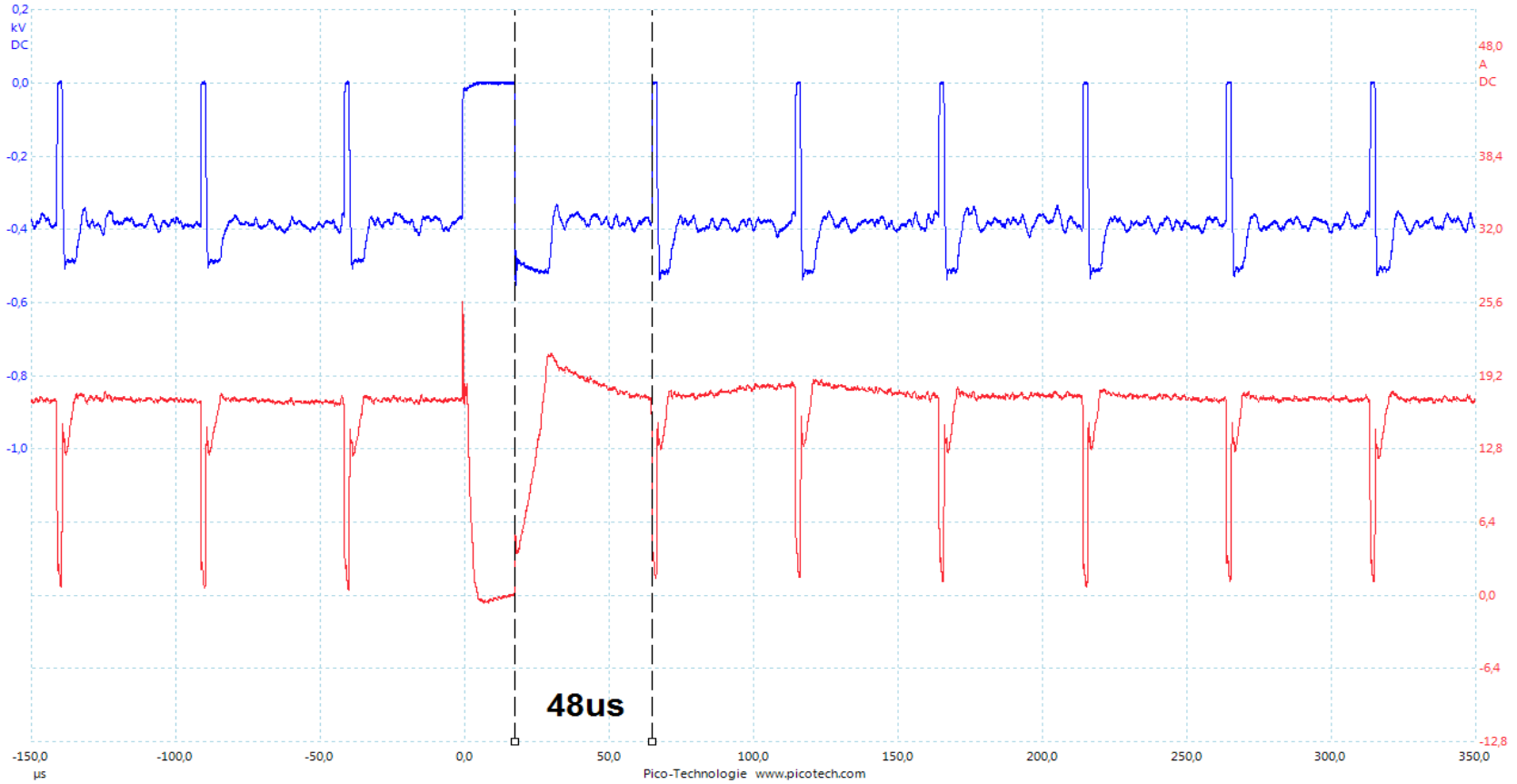

Figure 8: Arc event at end of pulse period on larger time scale
- Voltage - Current

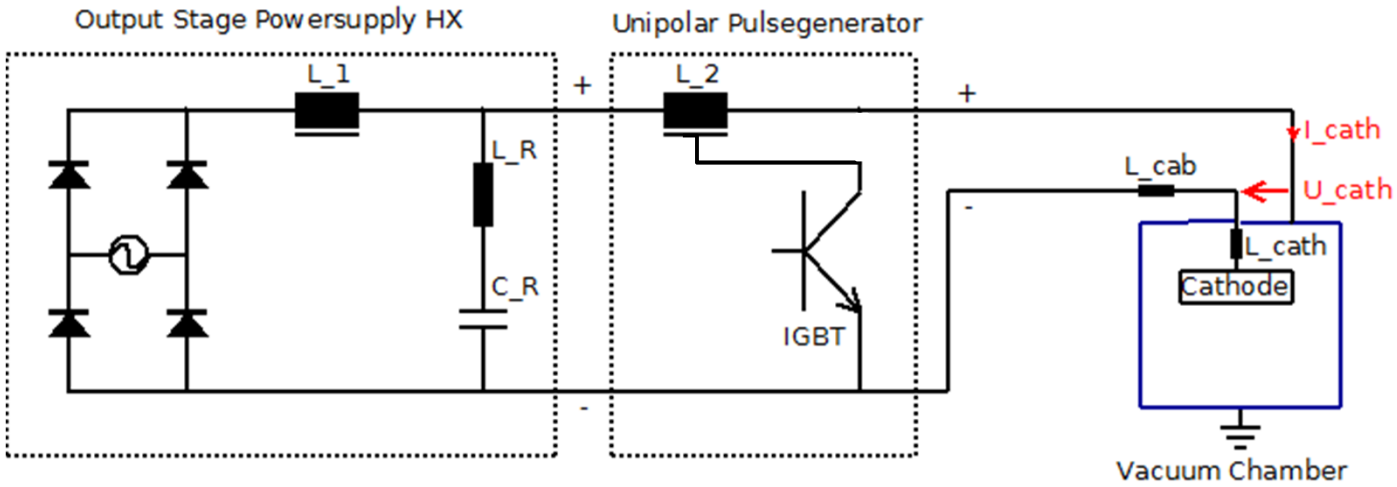

Figure 9: Unipolar Pulse Generator connected between HX and Vacuum Chamber

- Resonant circuit of HX is blocked by large inductance L_2 of pulse generator
- ONLY arc management of pulse generator is active
- Switching IGBT at tap of L_2
- Current sourcing pulse unit principle
- Active arc handling, switch off with IGBT during arcing

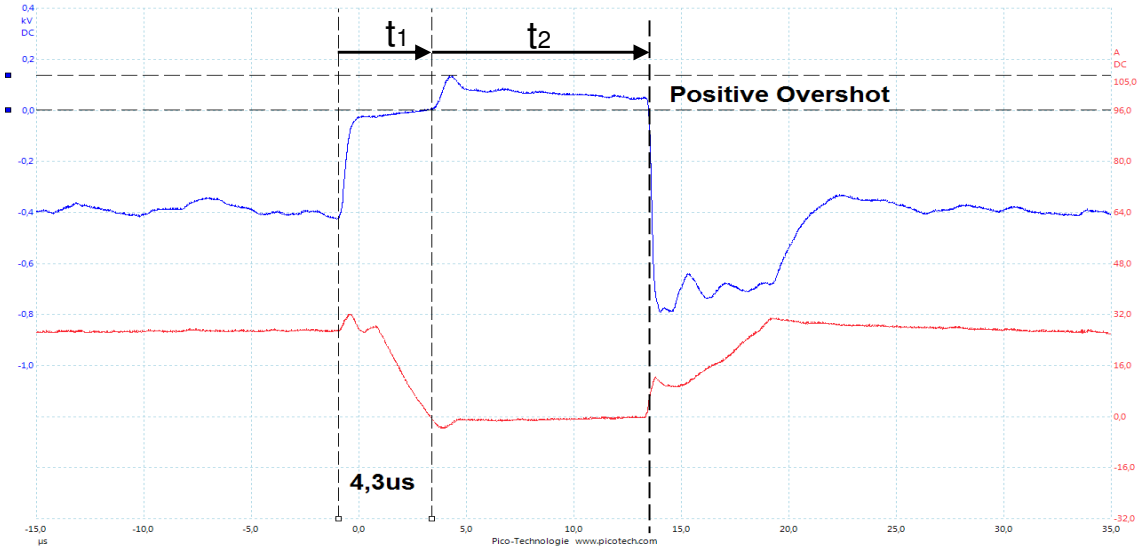

Figure 10: Voltage and Current waveform during arc event with reverse pulse

- Voltage - Current

t_1 – variable, depending on current and cable / cathode inductance

t_2 – Pause time variable, automatically adjusted

- At t = 0 an arc event occurs
- The cathode current increases rapidly
- Maximum 1.5 µs after arc occurs the generator shuts down
- Cathode current decreases and arc is quenched after 4.3 µs in this case
- The pulse generator restarts after additional 10 µs in this specific case
- Faster arc quenching and lower arc energy compared to SD150/300

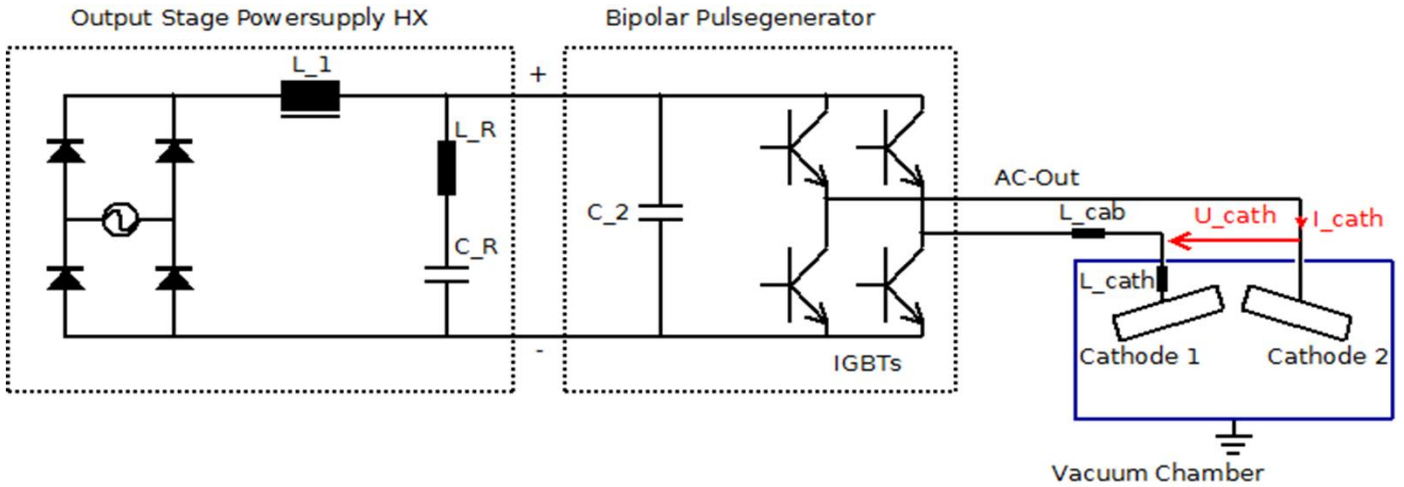

Figure 11: Bipolar Pulse Generator connected between HX and Vacuum Chamber

- ONLY arc management of pulse generator is active
- Capacitor C_2 holds voltage constant over half waves
- Switching H-bridge of IGBT and clamp diodes directly at the output of the pulse generator unit
- Voltage sourcing pulse unit principle

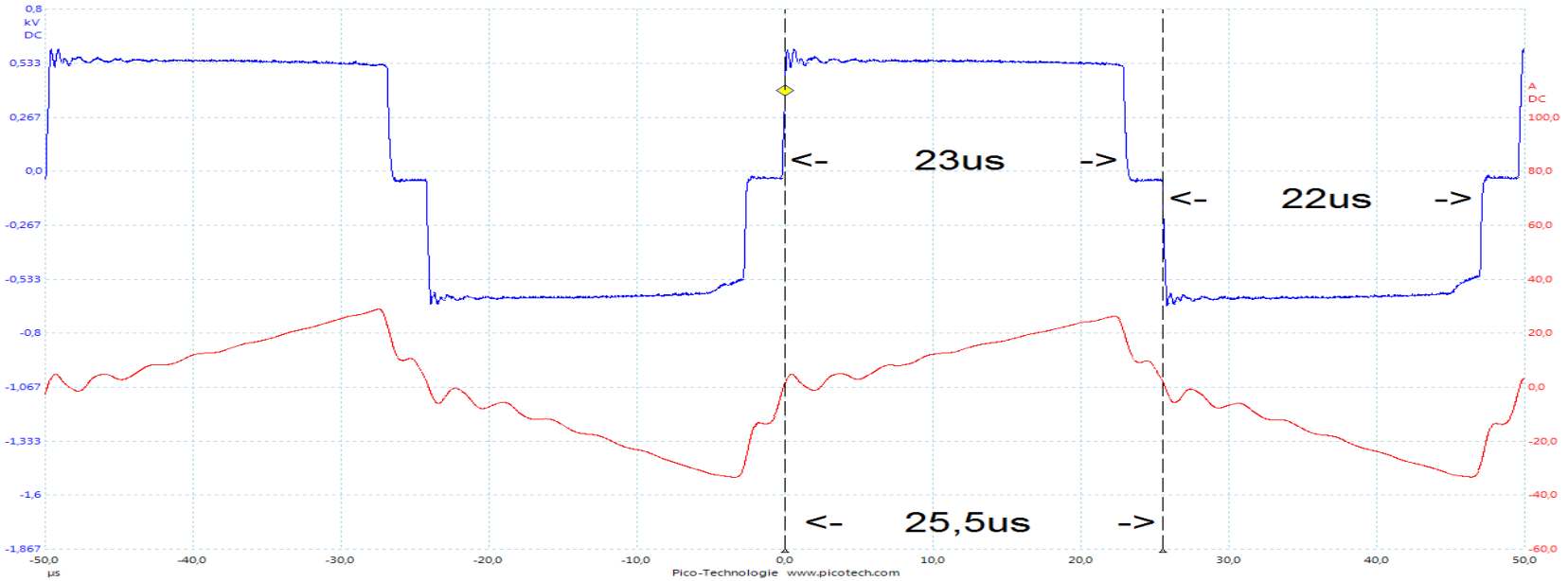

Figure 12: Voltage and Current waveform of SB300
- Voltage - Current

- Fixed setting of 20 kHz pulse frequency, unsymmetrical operation possible
- Fixed pause-time of 2.5 µs between positive and negative half wave
- Voltage constant and current ramps up during half wave

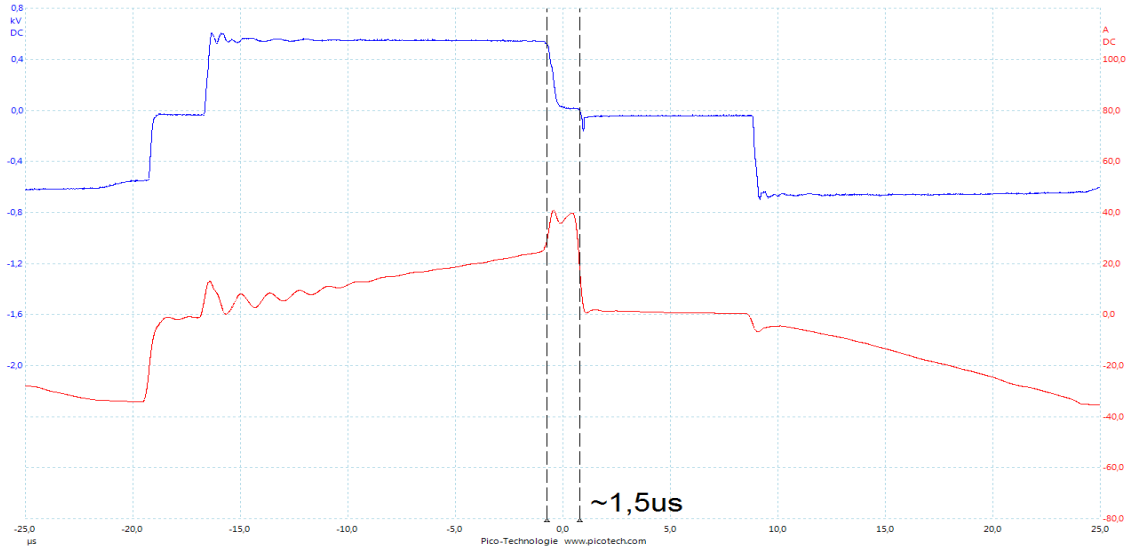

Figure 13: Voltage and Current waveform during arc event
- Voltage - Current

- At the end of the positive half wave an arc event occurs
- The cathode current increases rapidly and voltage collapses
- 1.5 µs after the arc occurs, it gets quenched
- For the remaining time of the half wave there will be paused
- The SB300 pulse generator restarts with the next half wave

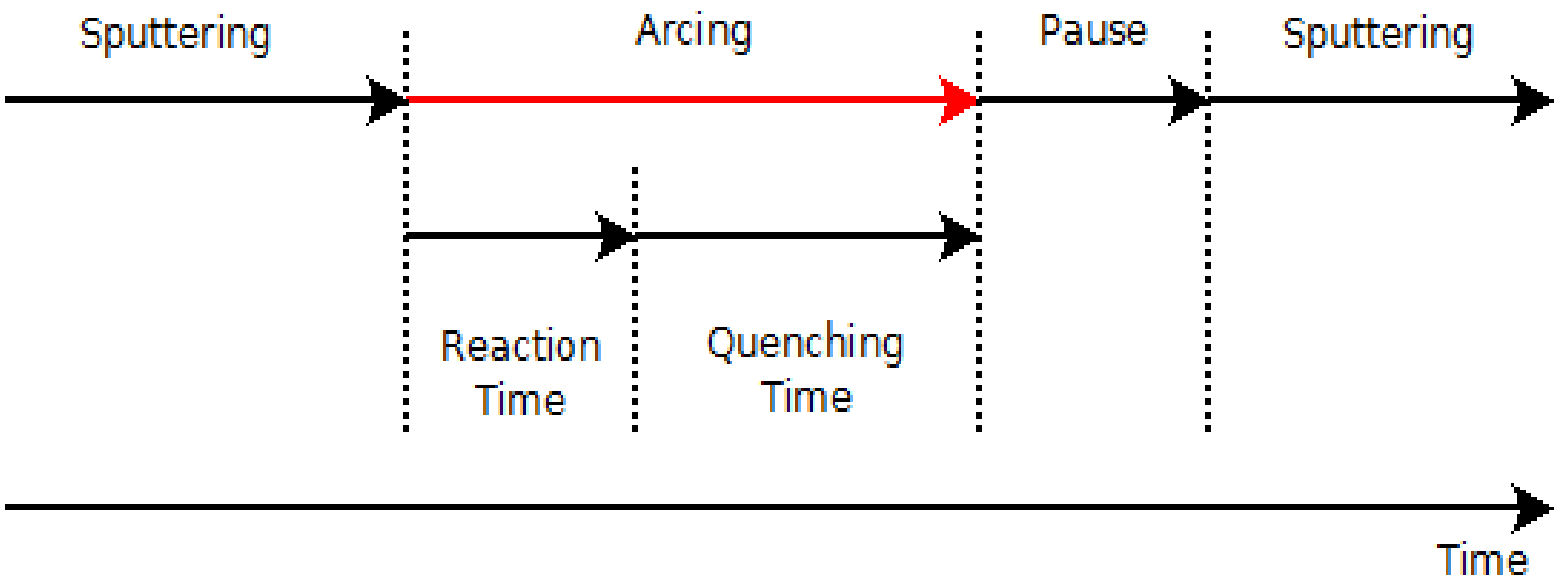

Figure 14: Different time periods during arc events

Overview of arc-measurements

	DC Power-Supply (HX 300/800)	Pulsed DC (HX 300/800 + SD 300)	Bipolar Pulse (HX 300/800 + SB 300)
Measurement Conditions - Regulation-Mode of DC-Unit - Output Power of DC-Unit - Output Voltage of DC-Unit - Output Inductance L_{out}	 Power 10 kW ~ 450 V ~ 2 µH	 Power 10 kW ~ 450 V ~ 2 µH	 Power 10 kW ~ 560 V ~ 2 µH
Reaction Time	0 µs	< 1,5 µs	< 1 µs
Quenching time	7 µs	~ 5 µs (variable)	~ 0.5 – 1.5 µs
Pause	0 µs (no shut down)	~ 12.5 µs (variable)	0 – 22.5 µs
Process to eliminate the arc	Reverse current achieved by resonant circuit	Short circuit the cathode current until it is almost zero, then a pause.	Open circuit, start with new pulse.
Arc energy	~ 2.5 mJ/kW	~ 0.25 mJ/kW	~ 0.15 mJ/kW
Maximal output inductance	Max. 10 µH for cable + cathode	Max. 10 µH for cable + cathode	Max. 10 µH for cable + cathode
Maximal arc-handling per second	~ 40.000 without clamp diode ~ 75.000 with clamp diode	50.000	40.000

Sinewave - Pulse: comparing different technologies

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	Sine-Wave	Actual competitors Bip-Power Supplies	Bipolar ADL Bip-Power Supplies
Ignition Voltage	1600 -2000V	1600 -2000V	500-1000V
Wave form voltage	Sine (distorted)	Trapeze descending after voltage peak	rectangle
Wave form current	Sine	Rectangle (distorted)	Trapeze ascending
Highest Arc-probability	Mid of Half-Wave 90° and 270°	Start of Half-Wave O° and 180°	End of Half-Wave 180° and 360°
Arc-Energy	big	low	low
Voltage-Difference Cathode 1/2	medium	big	low
Power-Difference Cathode 1/2	low (Balanced with AC-coupling)	big (Simple control)	very low (Power ratio controller)
Over-Voltage Stress	low (Sine)	big (Voltage peaks)	no (Square wave)
Dimensions	big	medium	small

Thank You For Your Attention