

Transformerless High Voltage Pulse Generators for Bipolar Drive of Dielectric Barrier Discharges

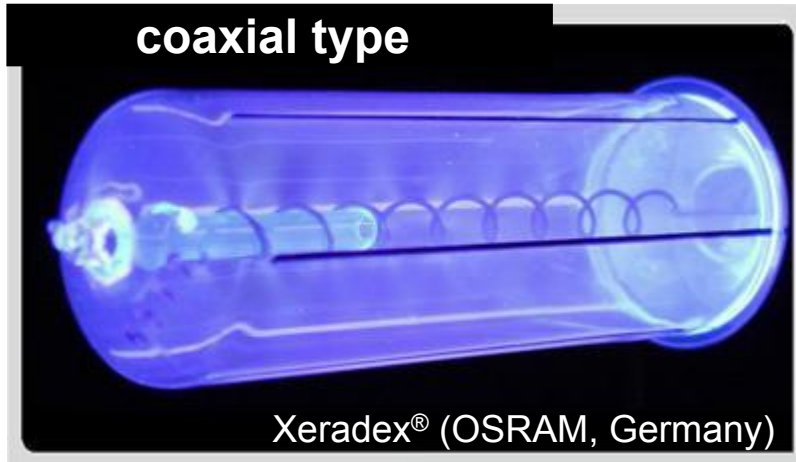
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Light Technology Institute (LTI), Department of Electrical Engineering and Information Technology



Dielectric Barrier Discharge (DBD) Lamps

coaxial type



plane to plane type



features:

- instant-on, no run-up
- long lifetime
- areal radiation
- various wavelengths
- mercury free

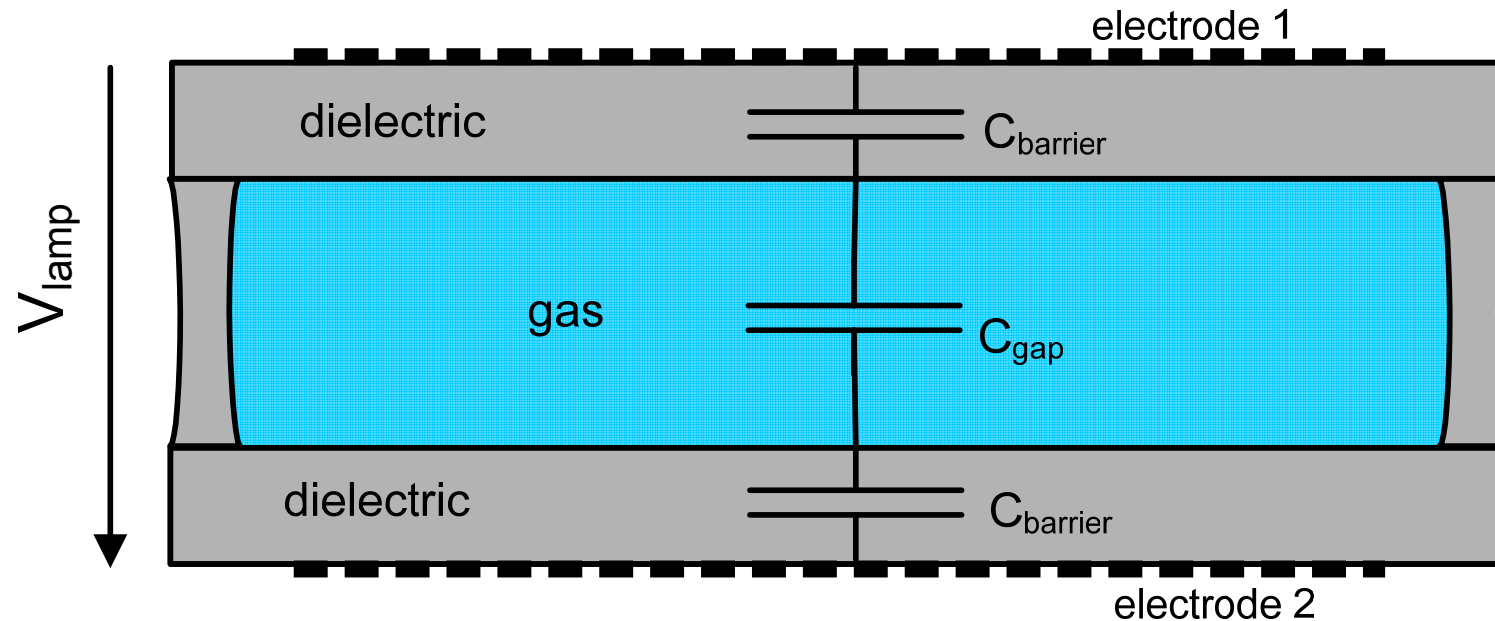
applications as UV light source:

- TFT display manufacturing
- surface modification

applications visible light source:

- scanners, copying machines
- ambient lighting

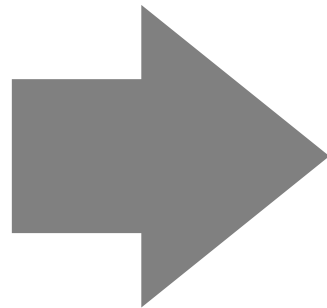
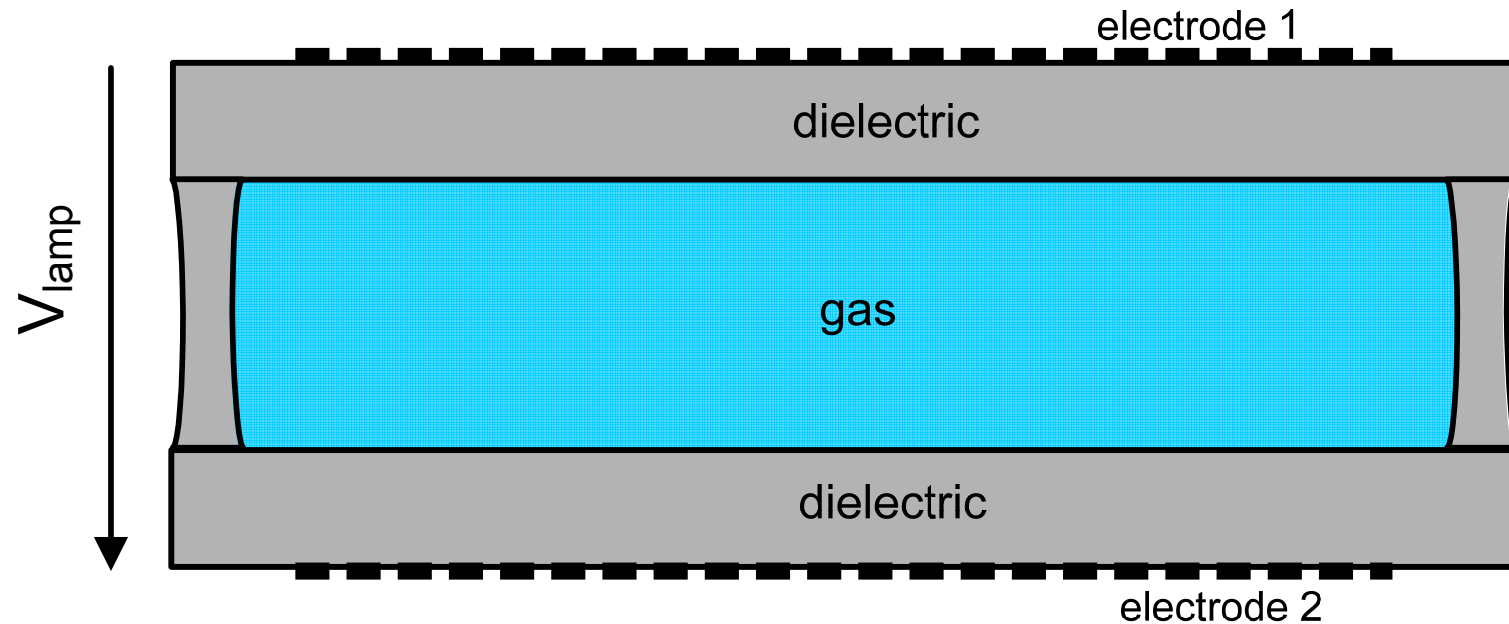
Dielectric Barrier Discharge Lamps – Set-up



electrical characterization:

- capacitive load $C_{\text{DBD}} = 3 \text{ nF}$
- low power factor 10 – 30 %
- dirac-like power consumption

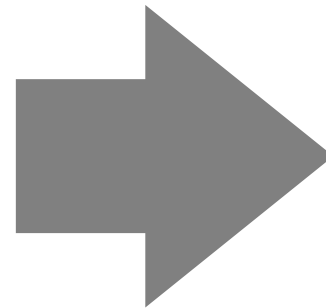
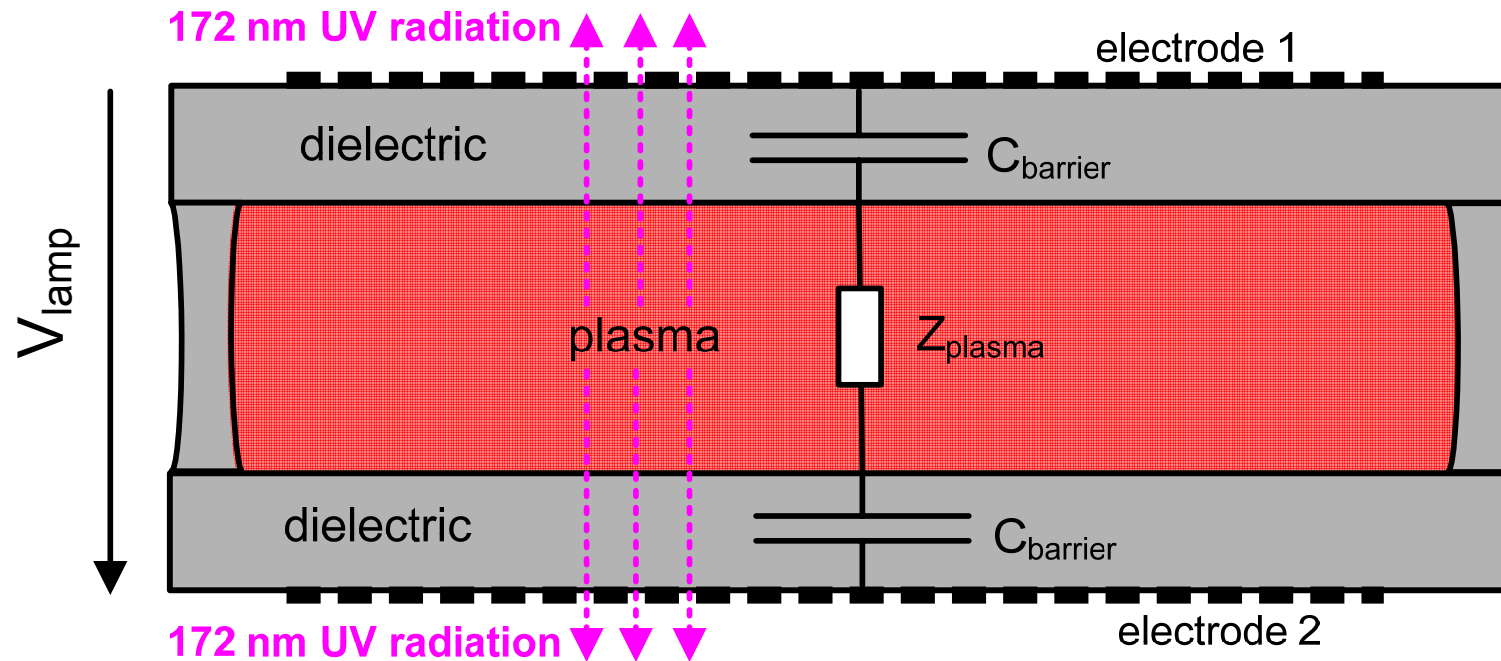
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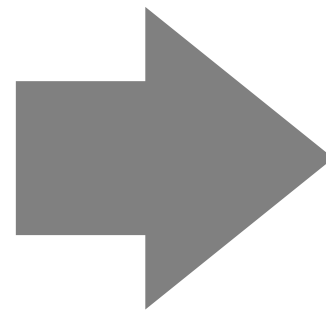
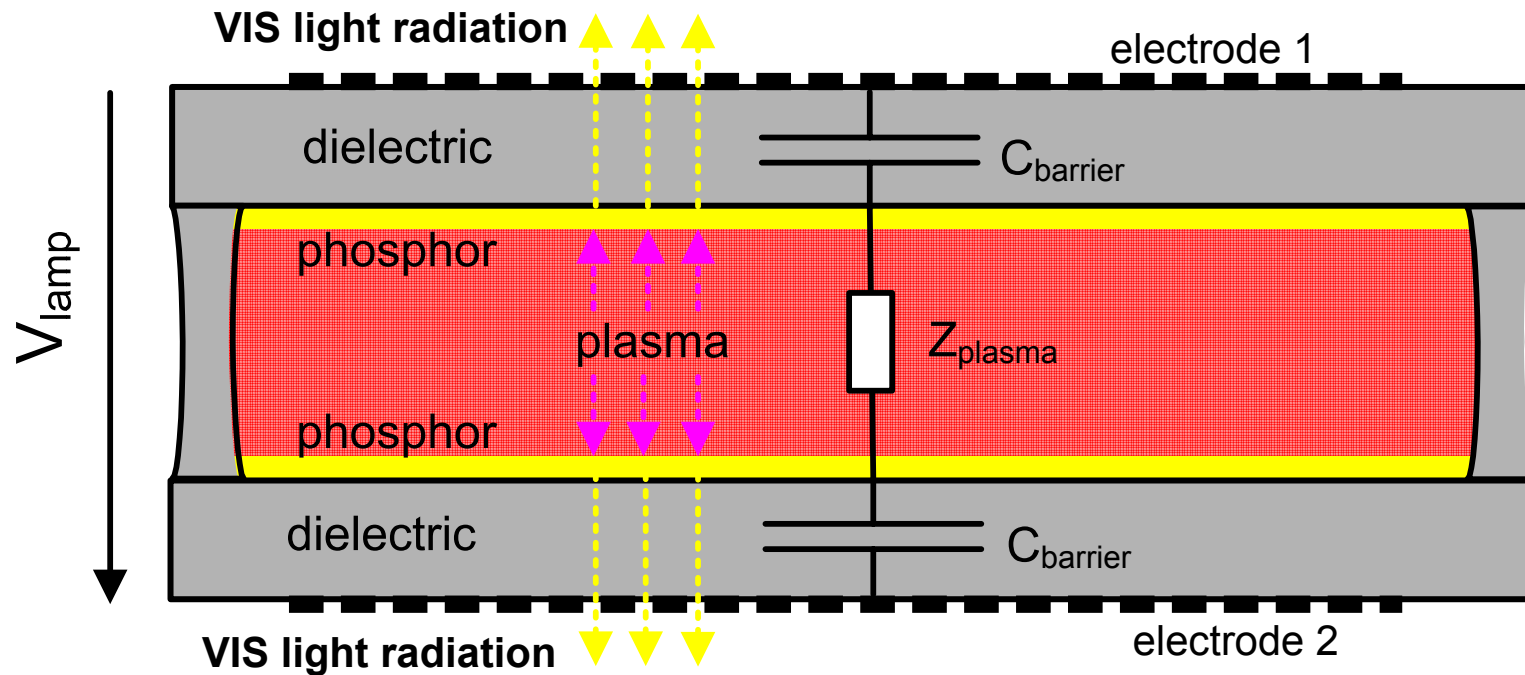
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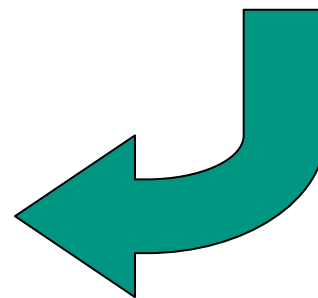
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Operation Requirements for DBD Lamps

- obtain lamp ignition
- lamp efficiency
- homogeneity of discharge



- high AC voltage amplitude (2 kV)
- high frequency pulsed operation
- bipolar pulse
- idle time between pulses



**requirements to
pulse generator**

- not continuous resonant operation! ▶ pulsed operation
- no continuous ZVS /ZCS possible
- higher peak currents for same output power

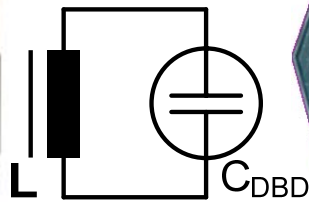
Fundamental Concepts



resonance

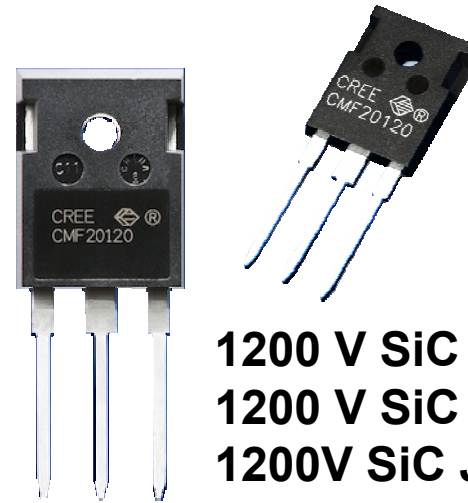
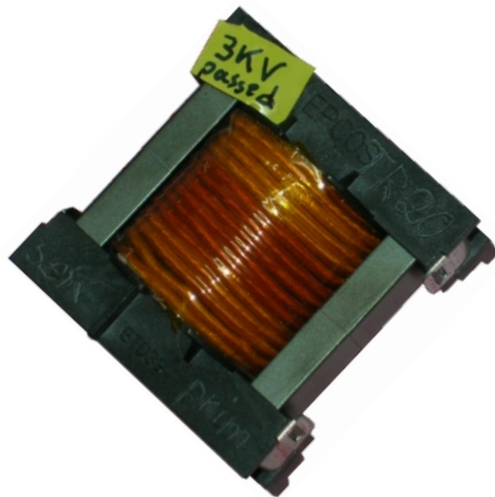


no transformer



1200 V SiC SBDs
1200 V SiC MOSFETs
1200V SiC JFETs

Transformer Versus High Voltage Switches



1200 V SiC SBDs
 1200 V SiC MOSFETs
 1200V SiC JFETs

- low supply voltage

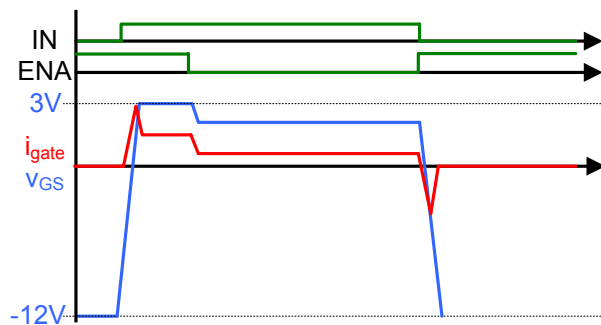
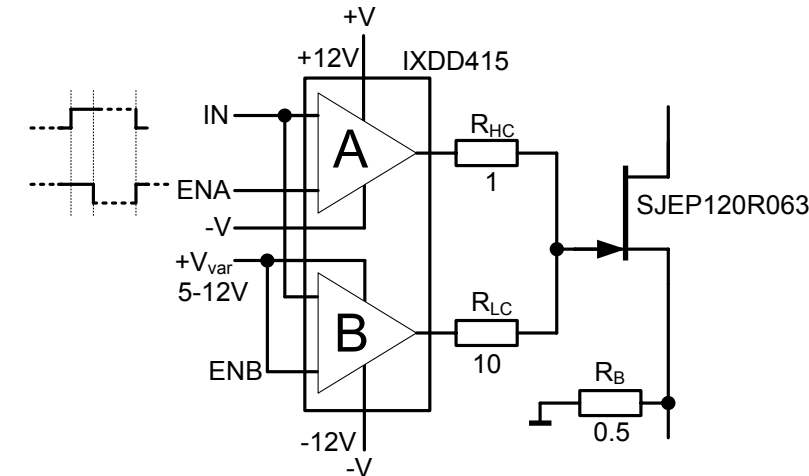
- high supply voltage
- higher possible pulse frequency

$$f_{pulse} = \frac{1}{2\pi \cdot \sqrt{(L + L_{stray}) \cdot C_{DBD}}}$$

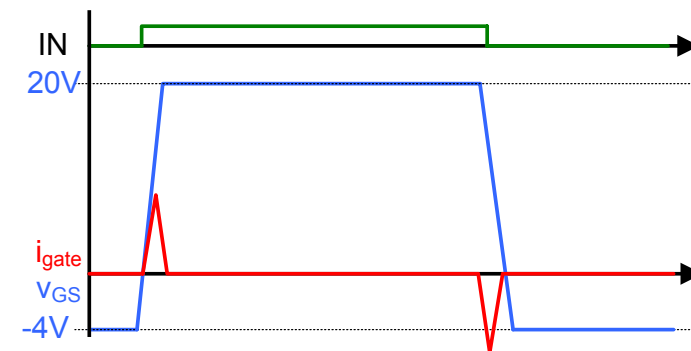
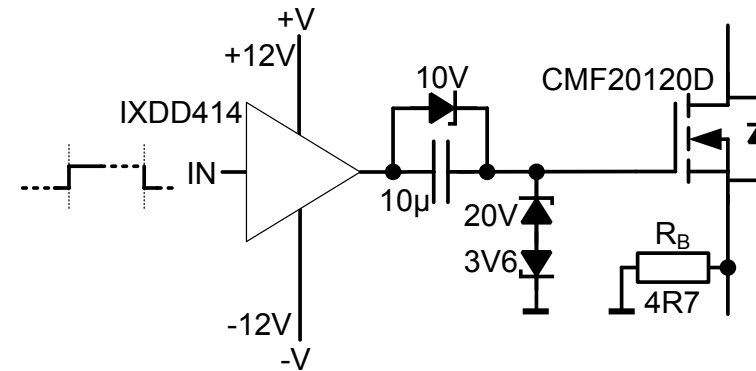
- no parasitic effects:
 - stray inductance
 - parasitic parallel resonance

Gate Driver for SiC Switches

■ SiC normally off JFET



■ SiC MOSFET

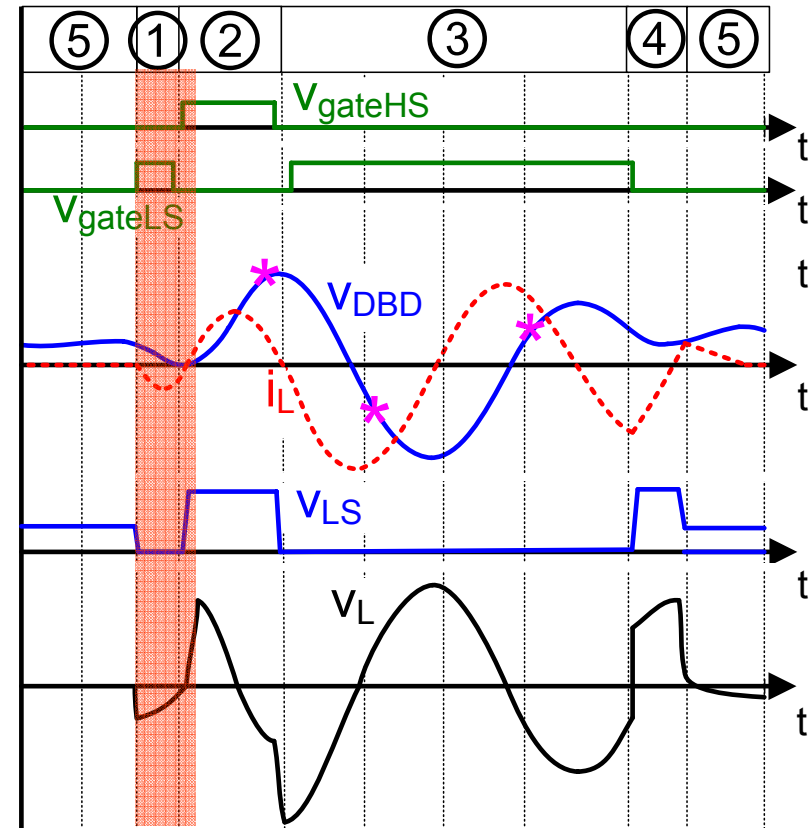
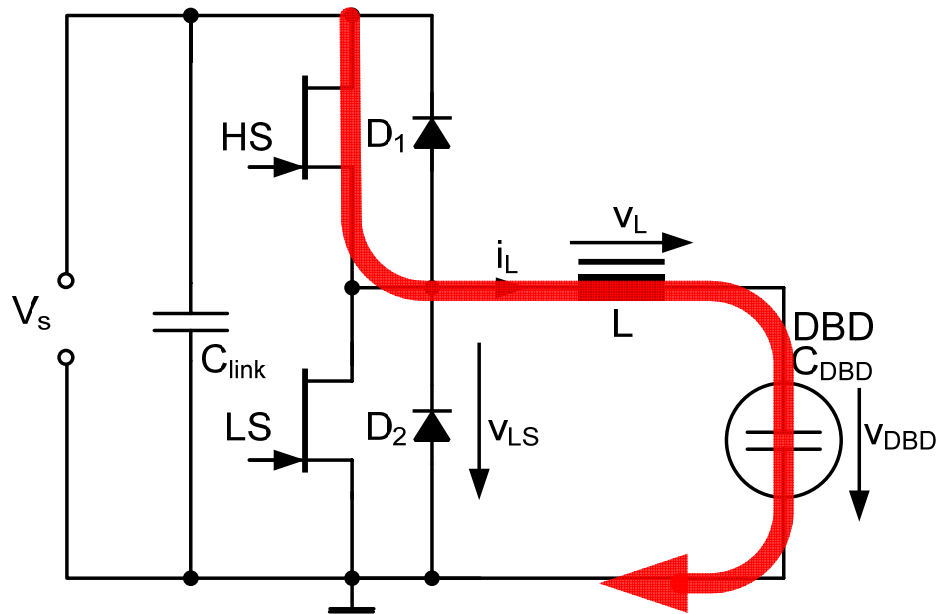


■ isolated symmetric power supply

■ optical signal transmission

HV Half-bridge with Optimized Operation Mode

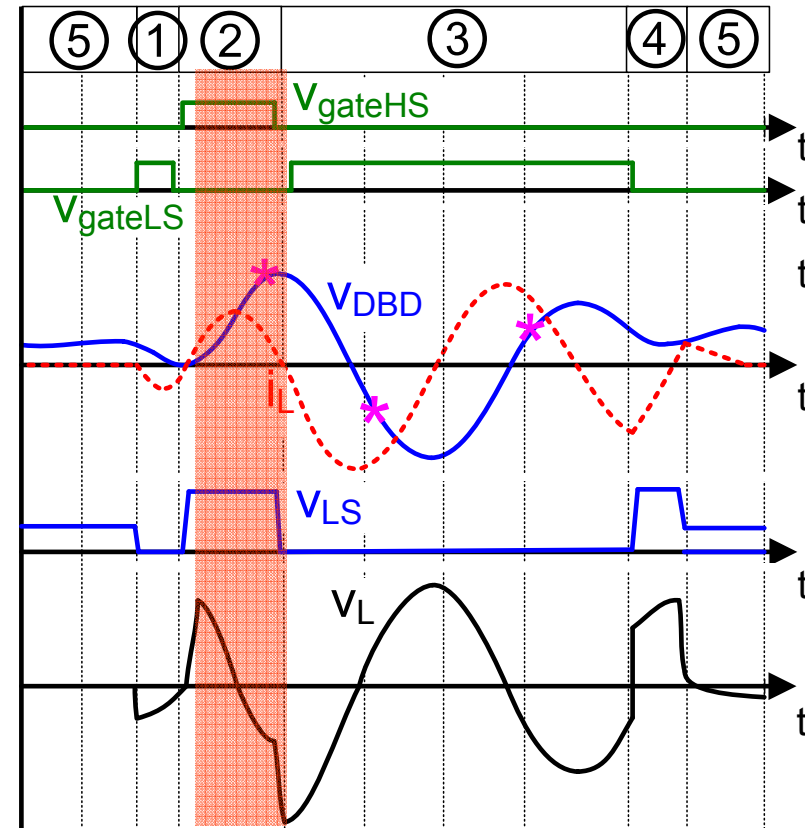
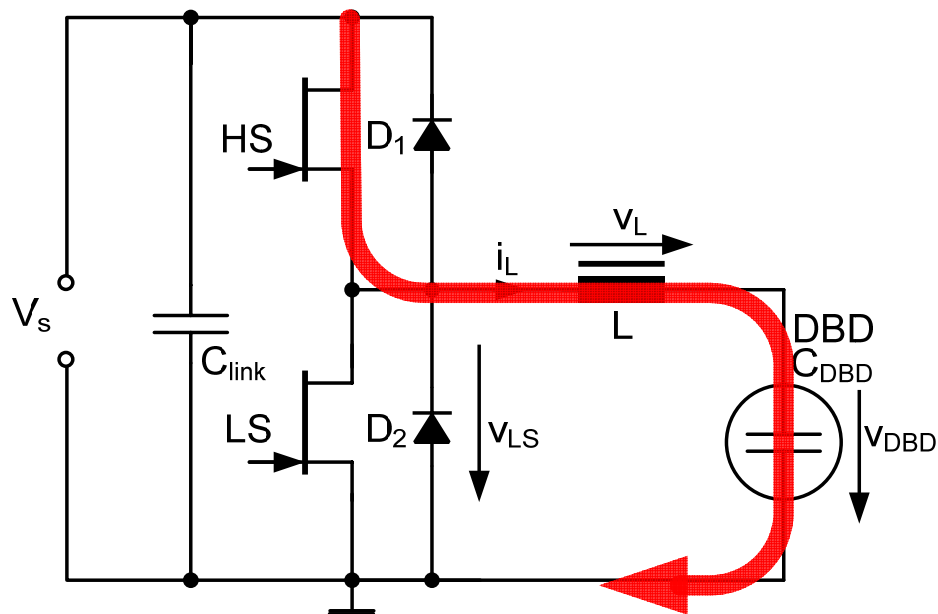
energy fed-in



- pre-pulse for maximum positive step
- positive V_{DBD} offset in idle time range

* time point of lamp ignitions

HV Half-bridge with Optimized Operation Mode

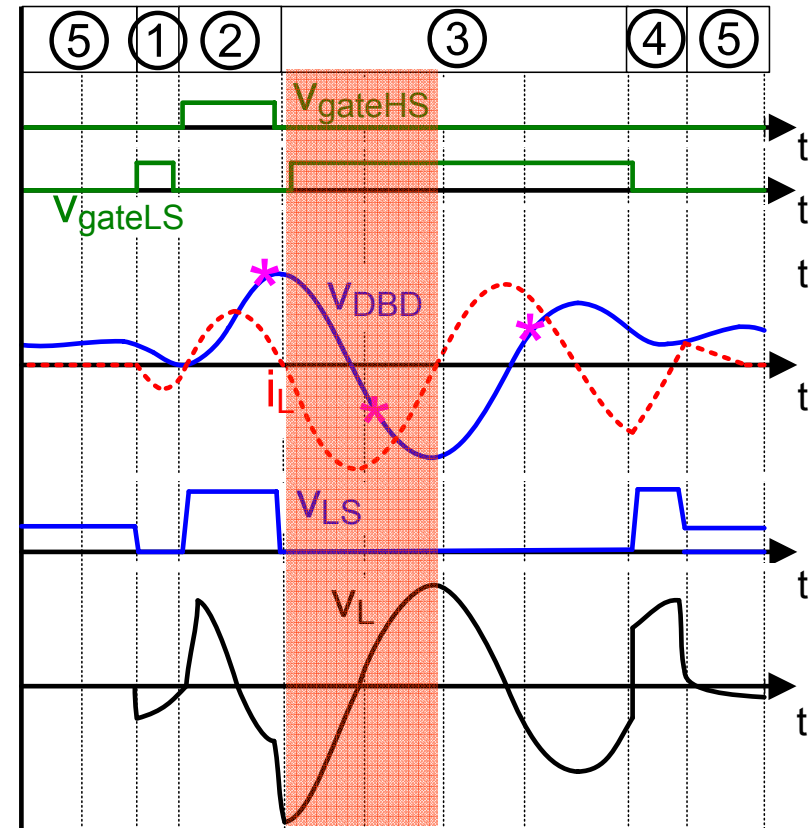
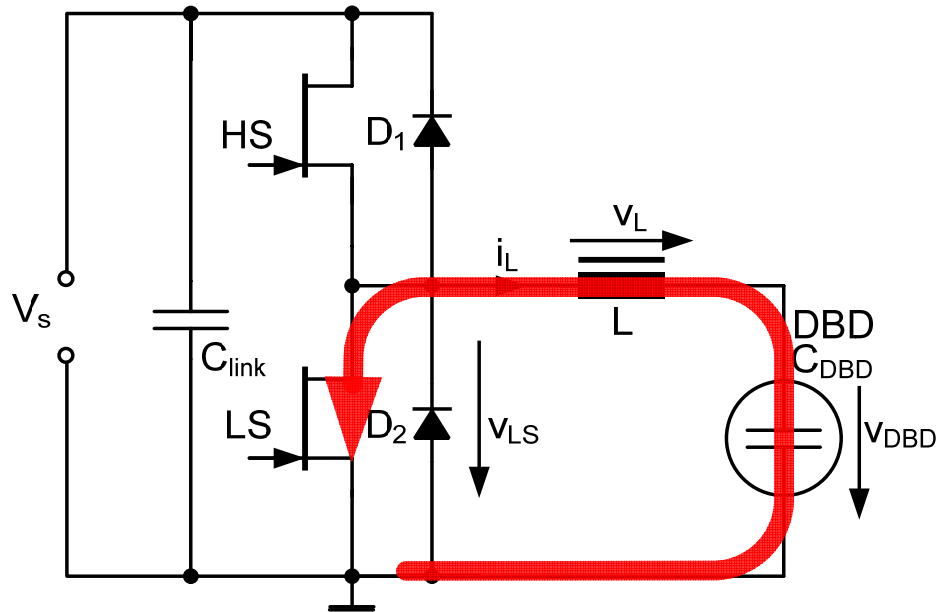


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HV Half-bridge with Optimized Operation Mode

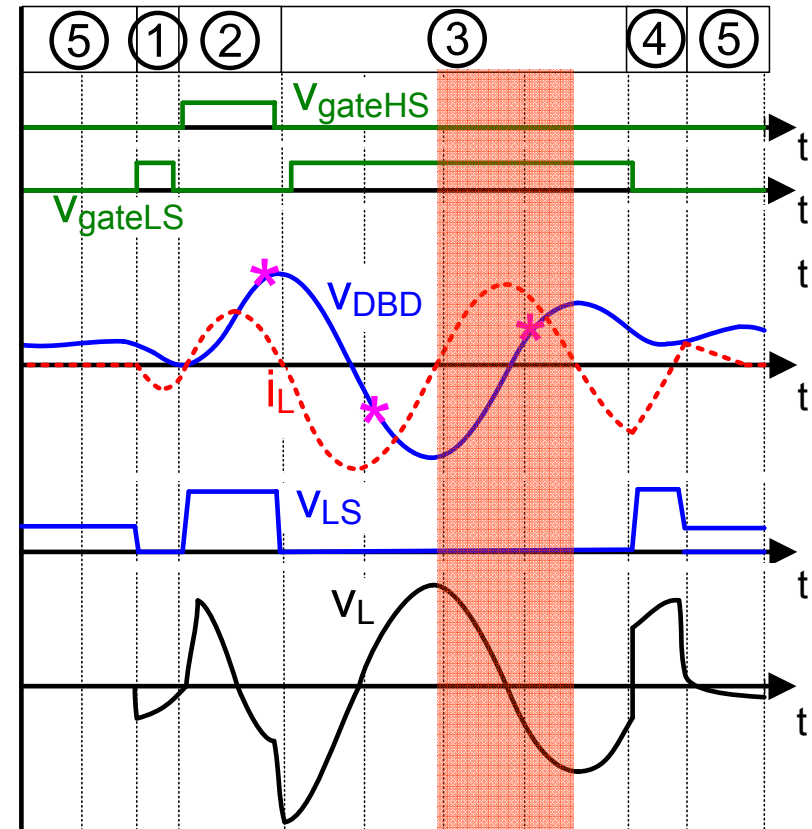
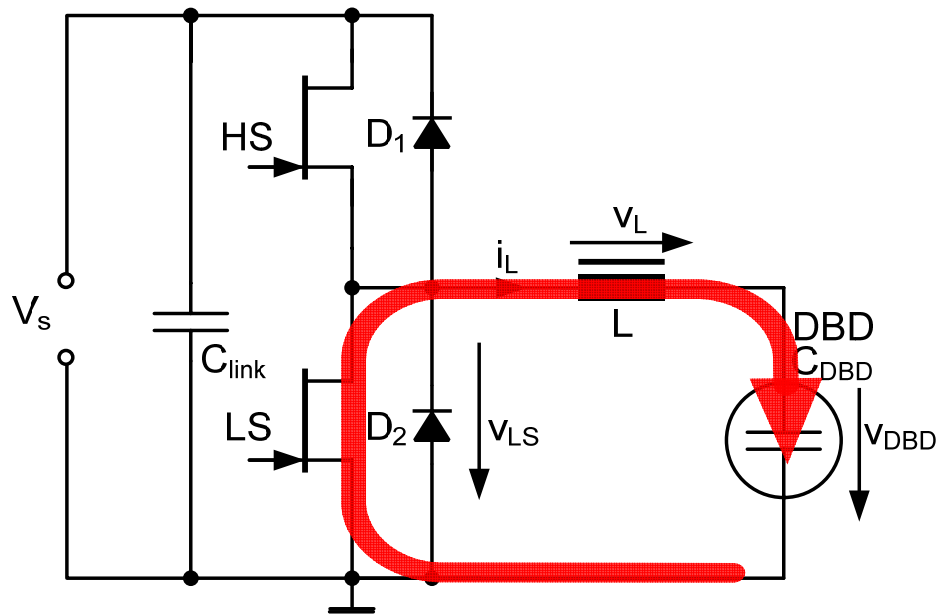
energy recovery



- pre-pulse for maximum positive step
- positive V_{DBD} offset in idle time range

* time point of lamp ignitions

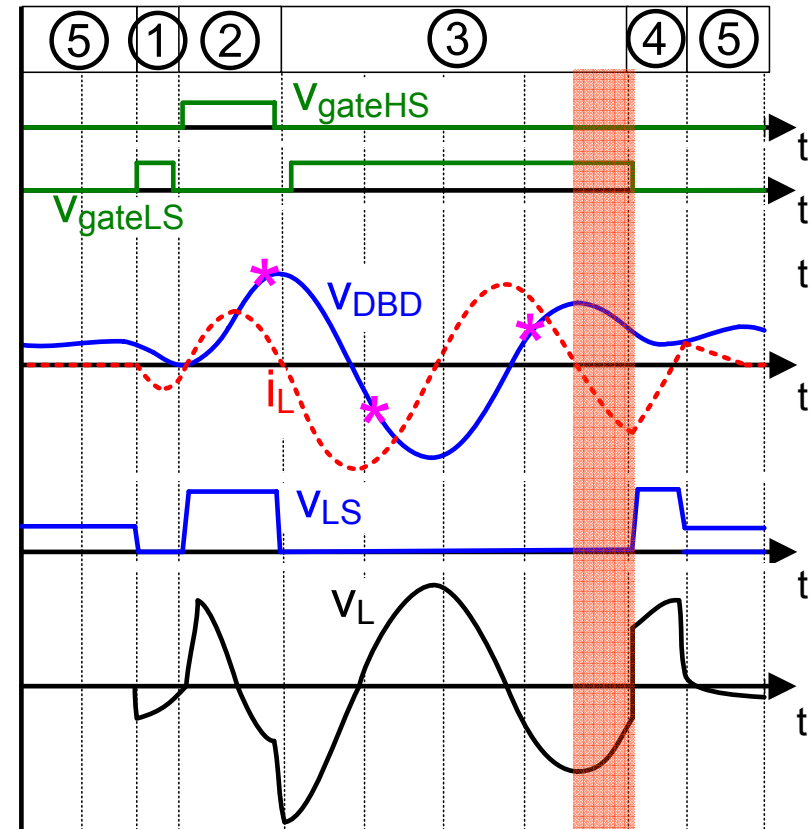
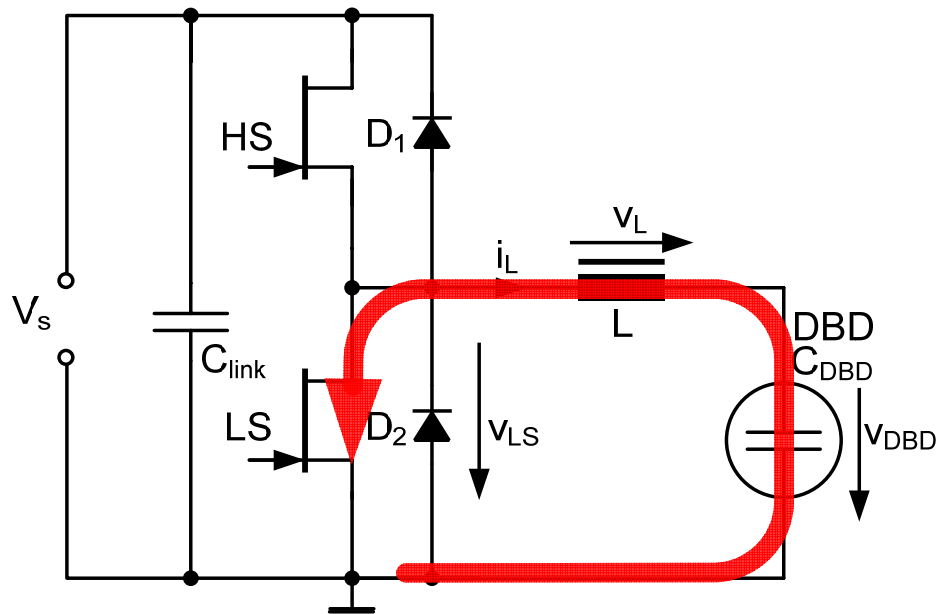
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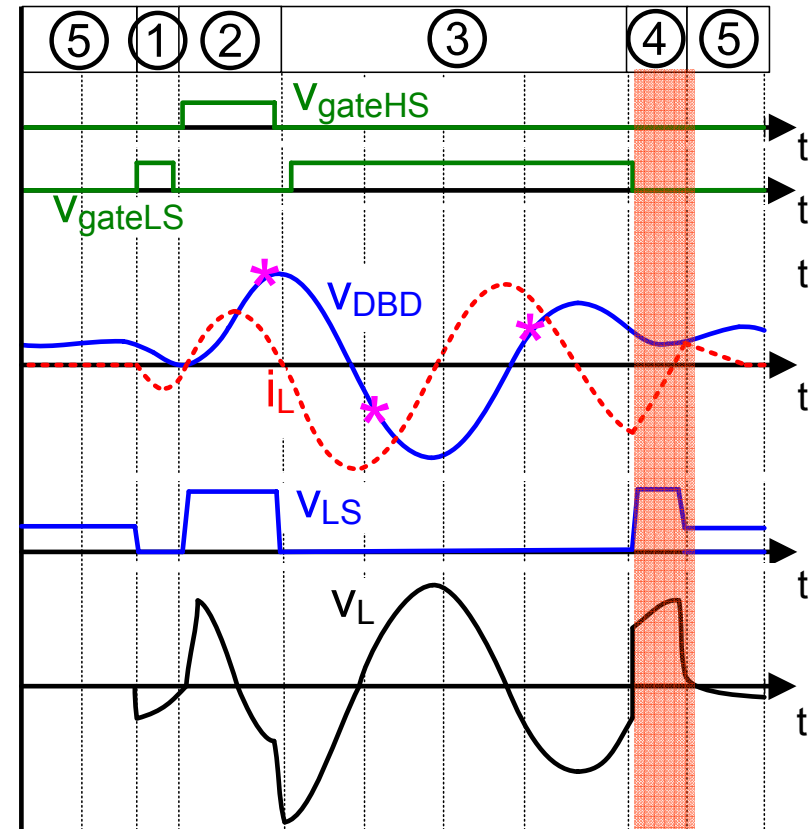
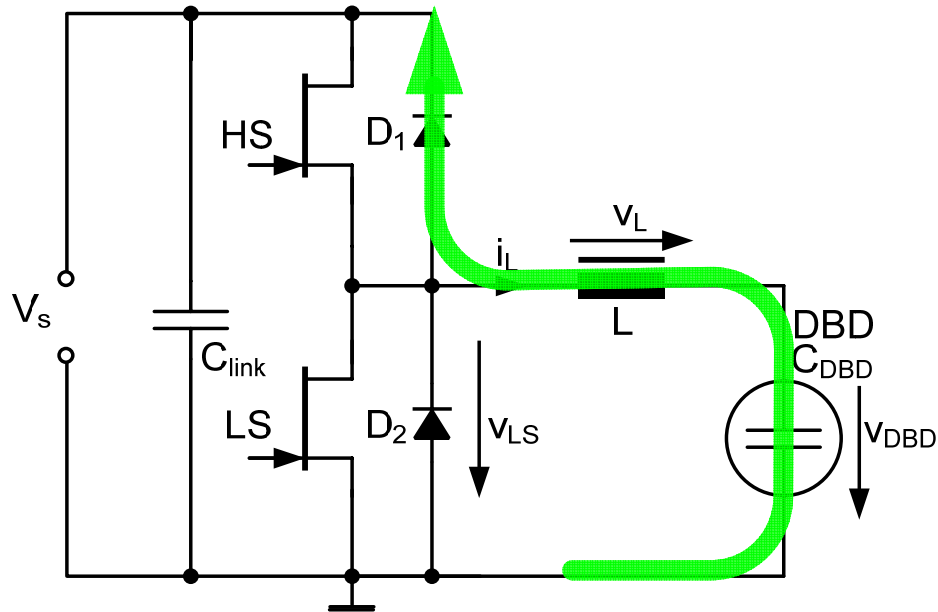


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HV Half-bridge with Optimized Operation Mode

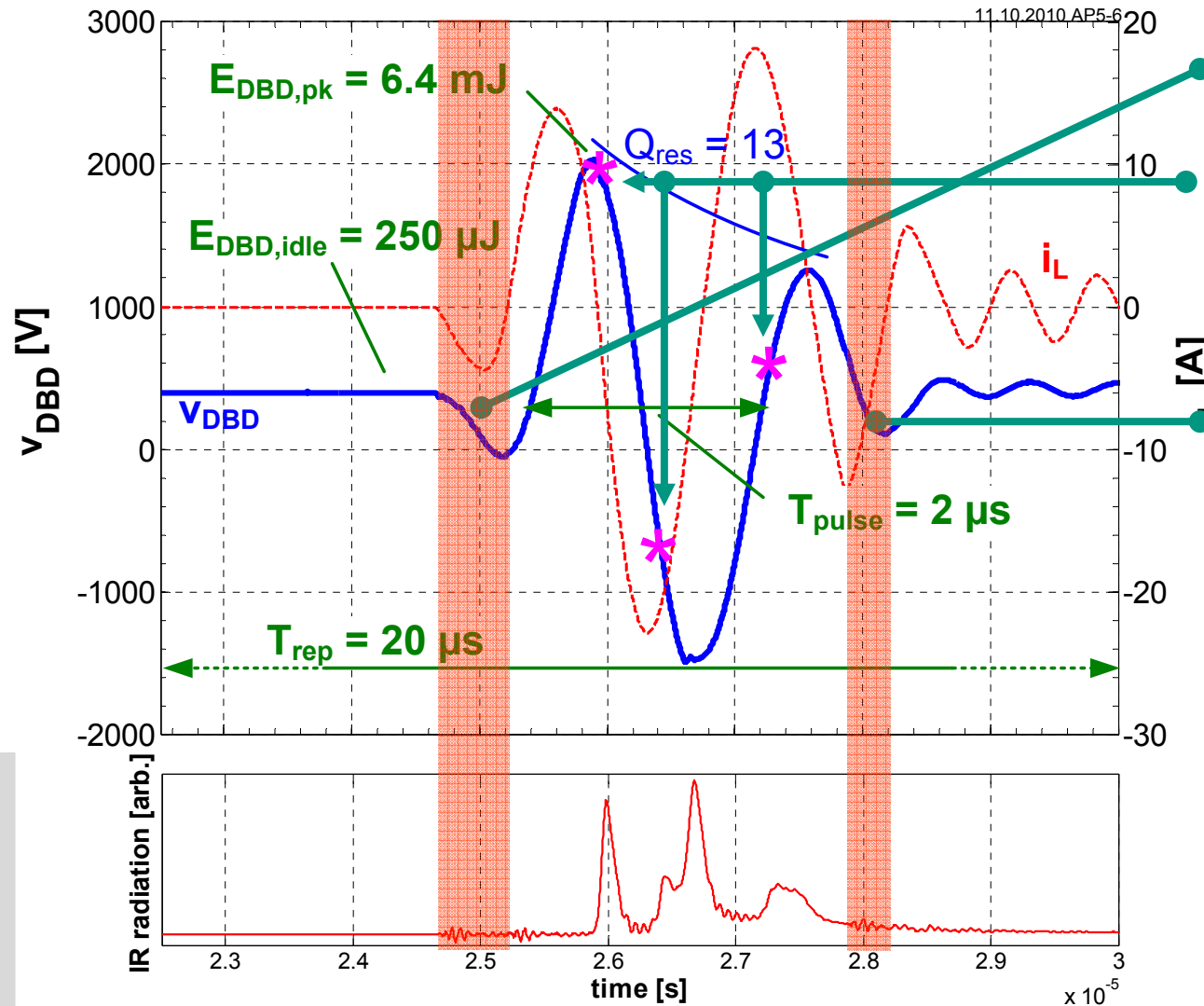
energy recovery



- pre-pulse for maximum positive step
- positive V_{DBD} offset in idle time range

* time point of lamp ignitions

Experimental Results



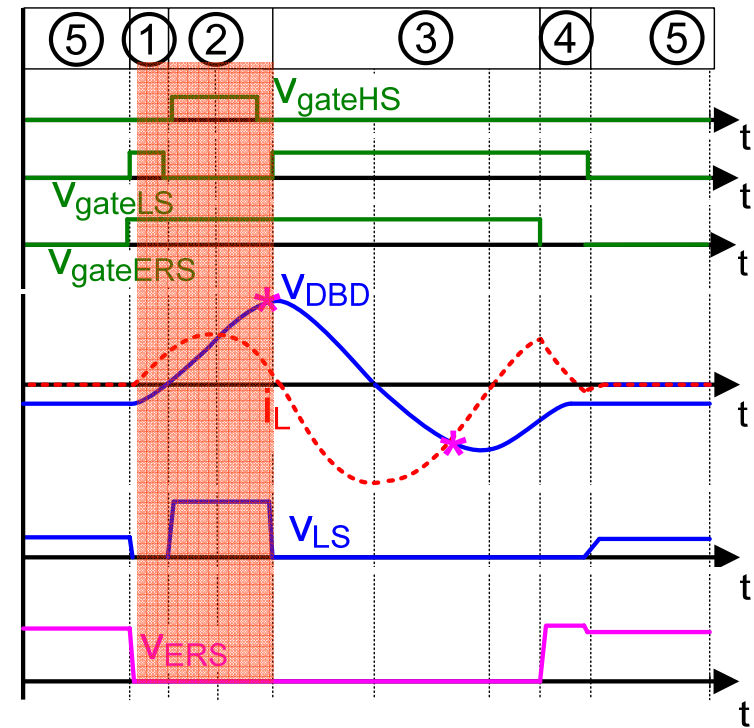
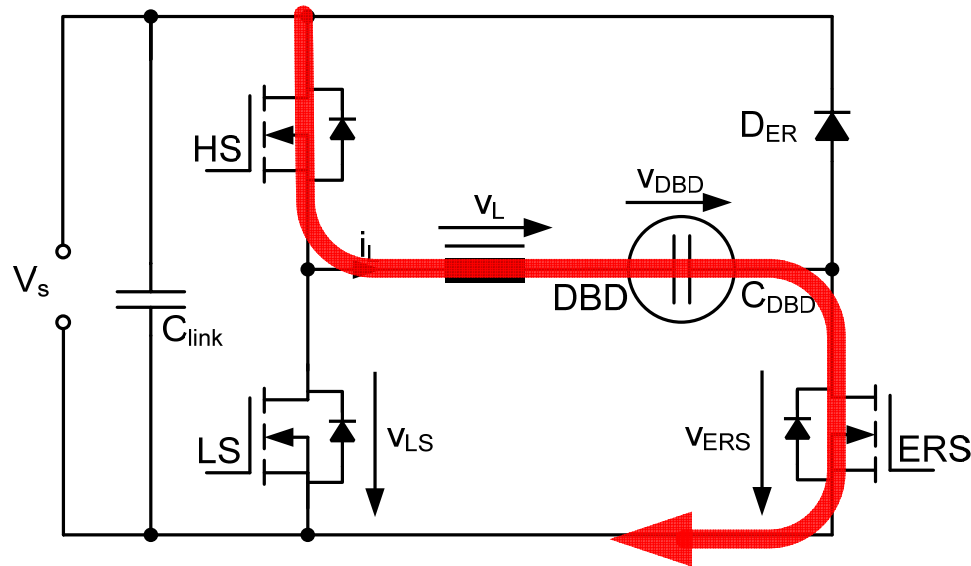
- pre-pulse for maximum up-swing
- 3 ignitions

■ energy recovery

■ parameters:

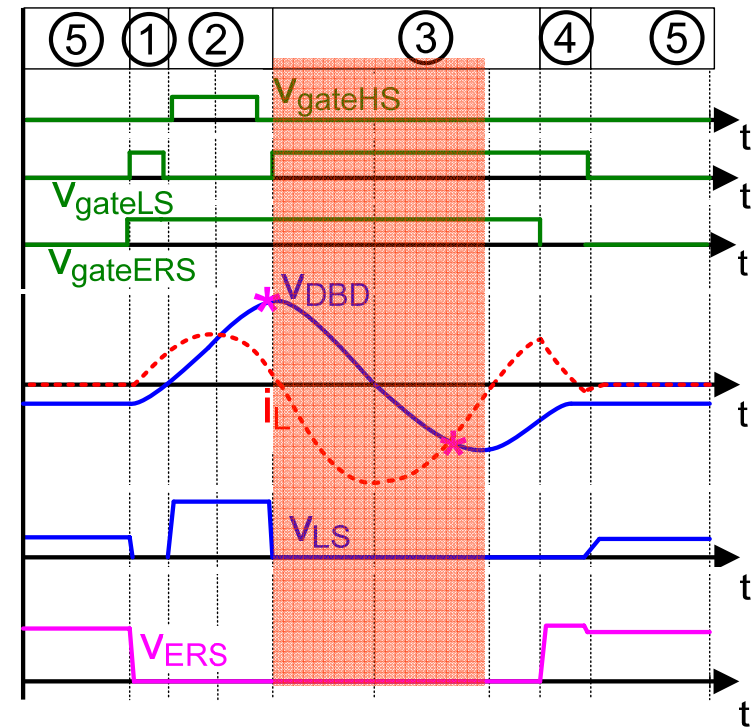
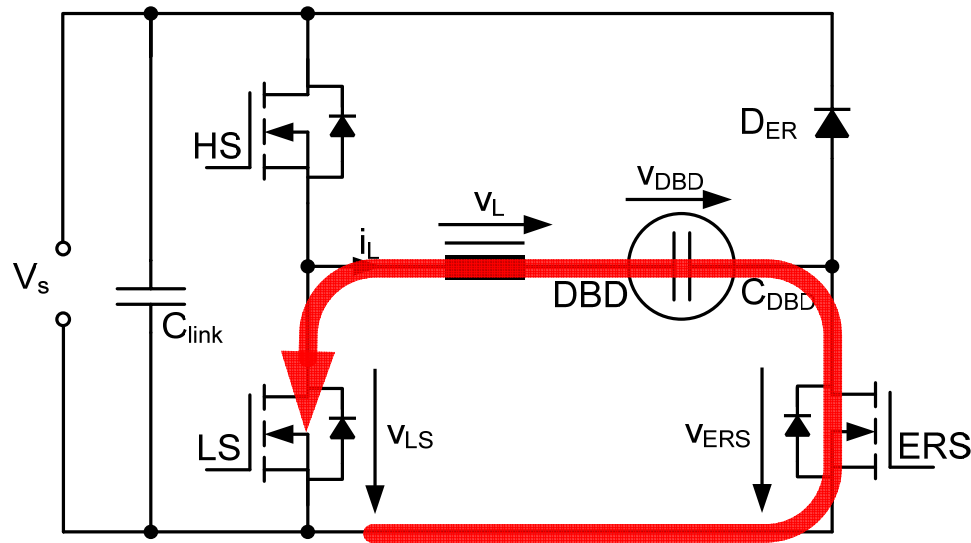
- $V_S = 1150 \text{ V}$
- $T_{rep} = 20 \text{ μs}$
- $f_{pulse} = 580 \text{ kHz}$
- $\eta = 70 - 88 \%$

HV Full-bridge Topology Operation Mode



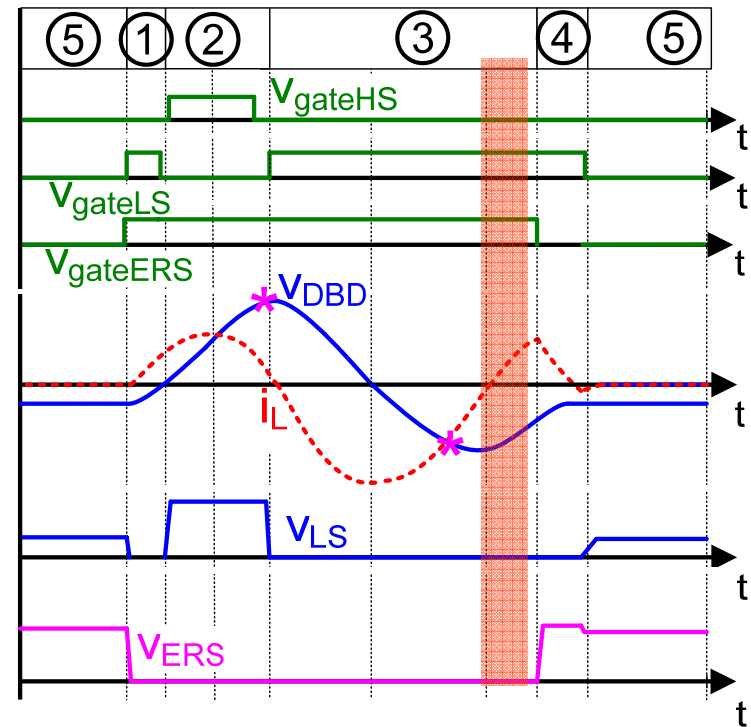
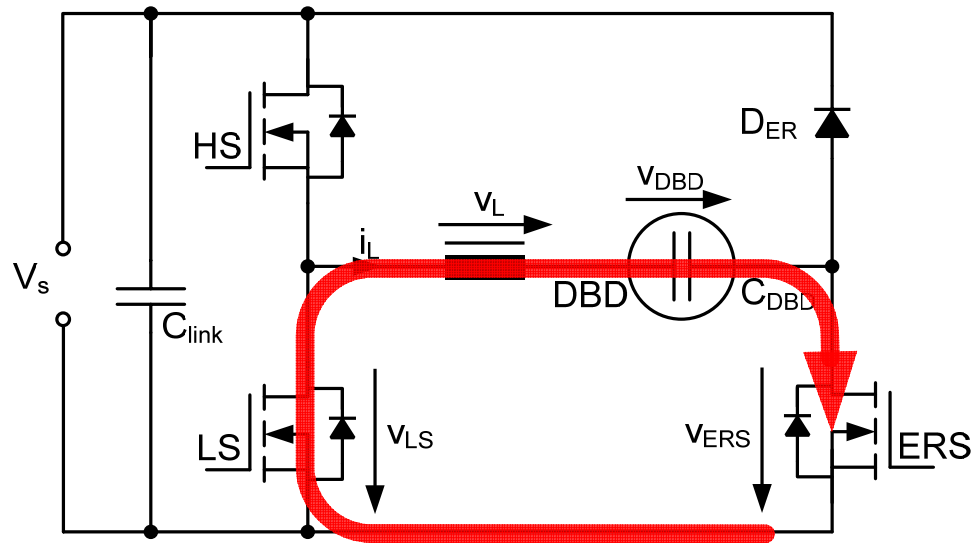
* time point of lamp ignitions

HV Full-bridge Topology Operation Mode



* time point of lamp ignitions

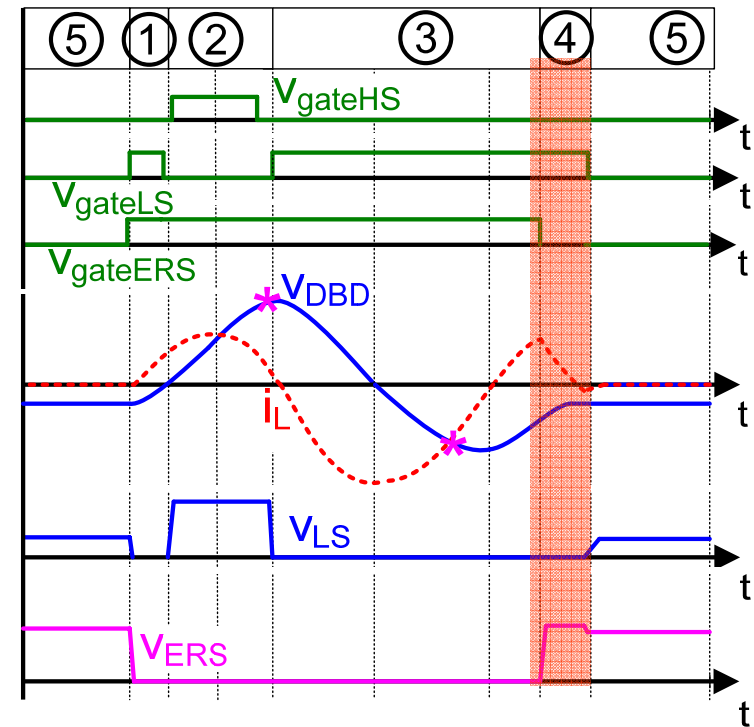
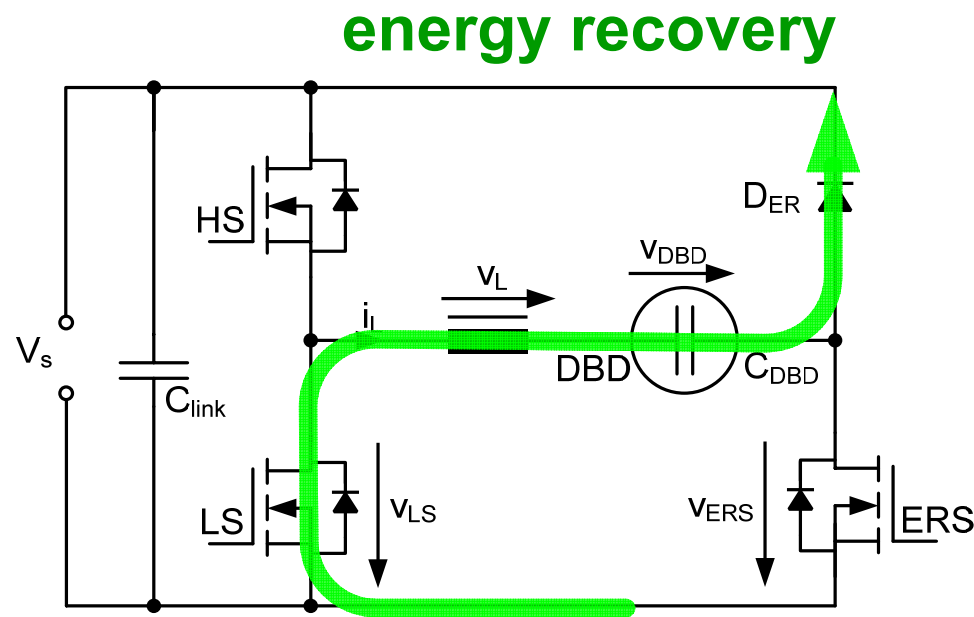
HV Full-bridge Topology Operation Mode



* time point of lamp ignitions

■ 3rd ignition prevented by earlier energy recovery

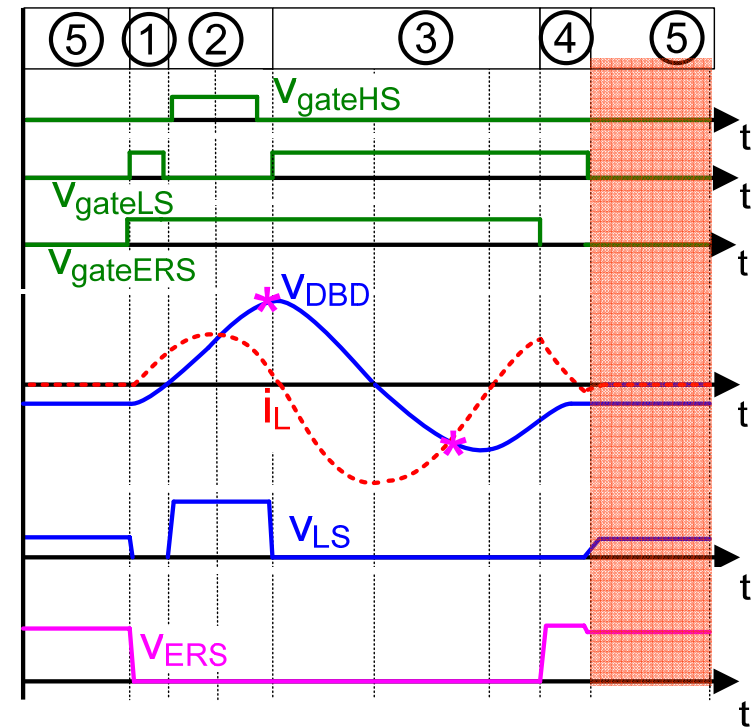
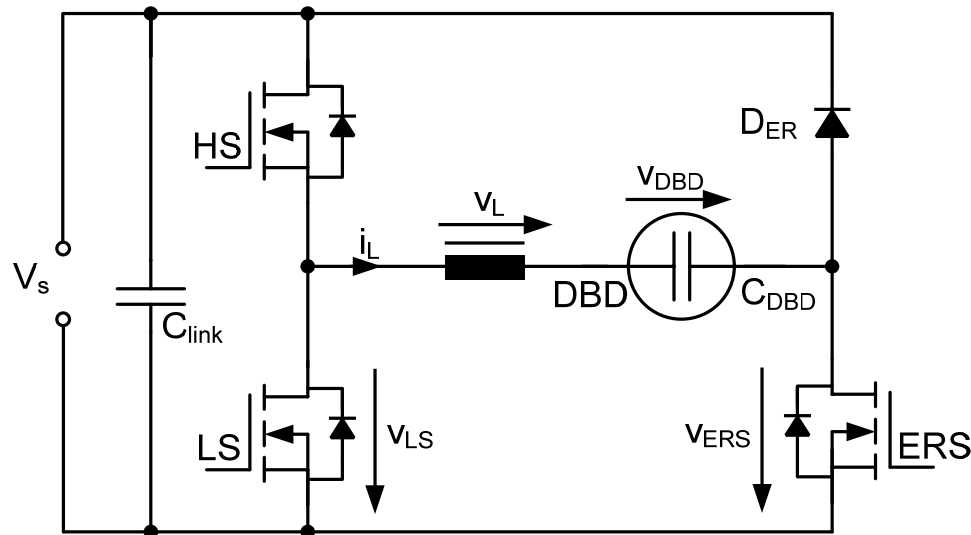
HV Full-bridge Topology Operation Mode



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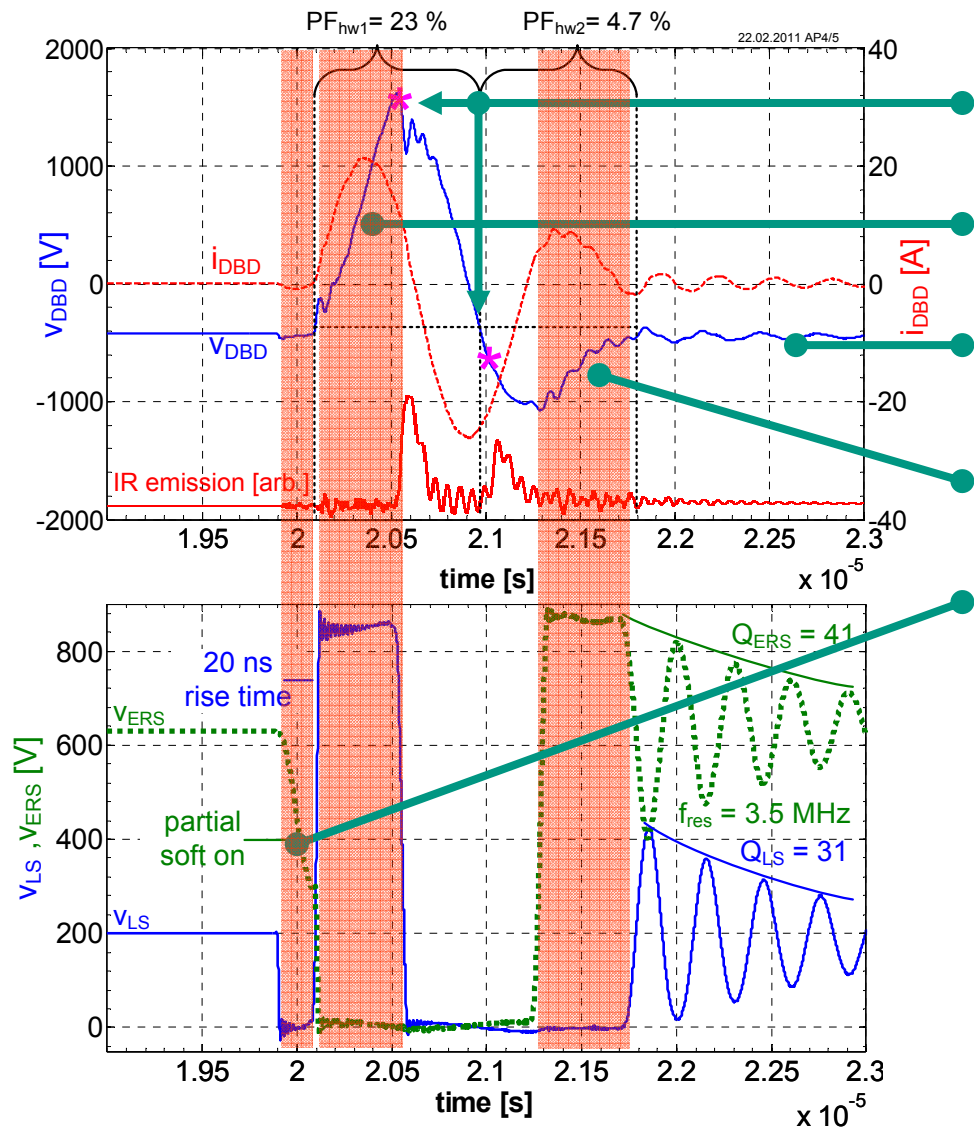
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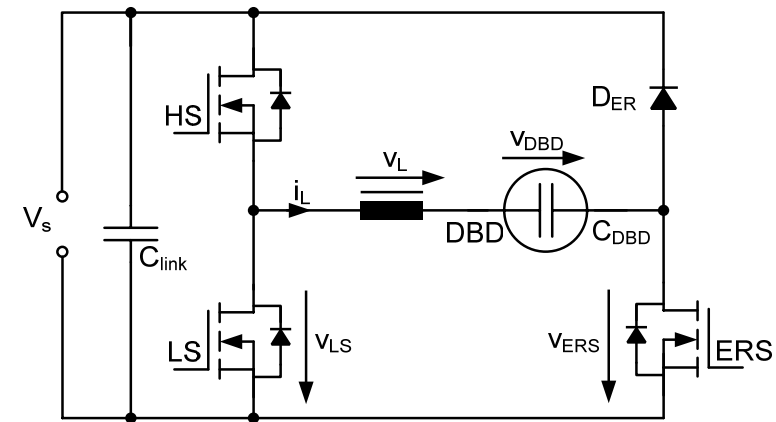
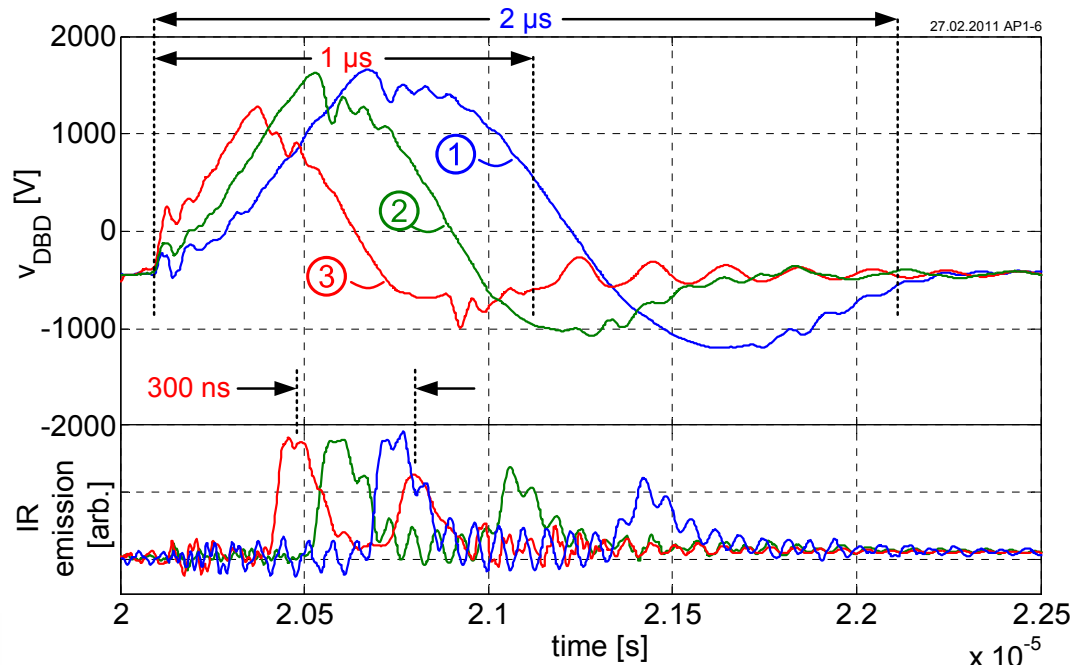
- 3rd ignition prevented by earlier energy recovery
- negative offset supports low outer ignition voltage

Experimental Results of Full-bridge Topology



- 2 ignitions
- energy fed-in
- negative V_{DBD} offset
- energy recovery
- partial soft turn-on
- parameters:
 - $V_S = 860 \text{ V}$
 - $T_{rep} = 40 \mu\text{s}$
 - $f_{pulse} = 600 \text{ kHz}$
 - $\eta = 50\text{-}86 \%$

High Frequency Operation



- pulse frequency up to **1MHz**
- rising Power Factor of 1st half wave
- rising peak current
- higher losses

	①	②	③
L	17u8	8u	2u6
f_{res} [kHz]	500	670	1000
V_s [V]	900	860	860
P_{in} [W]	100	106.7	110
$PF_{DBD, 1st\ half-wave}$ [%]	18%	23%	35%
$I_{l\ pk}$ [A]	19	26	35
η -range [%]	61-84	49-86	41-78

To Conclude

- DBD light sources require high frequency bipolar pulsed operation
- achieved with **transformer-less** half-bridge **SiC** diodes and switches
- high speed driver tailored to Silicon Carbide switches
- half-bridge topology vs. full-bridge topology
high efficiency
- pulse frequency up to **1 MHz**

