

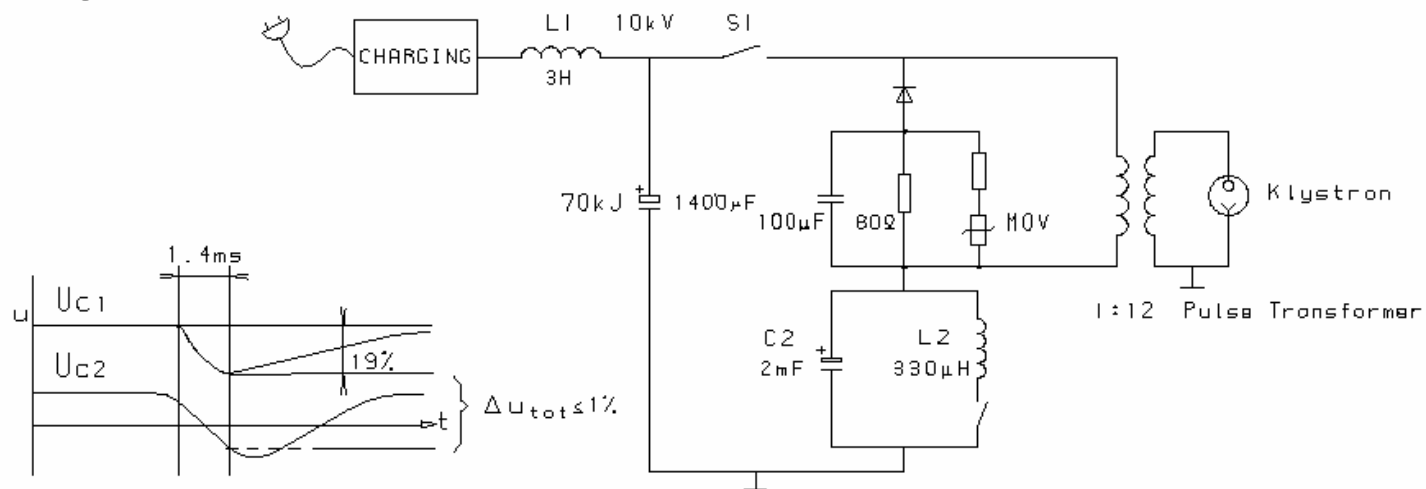
# Status of the industrial modulators at DESY and modulator plans for the XFEL

S. Choroba, DESY

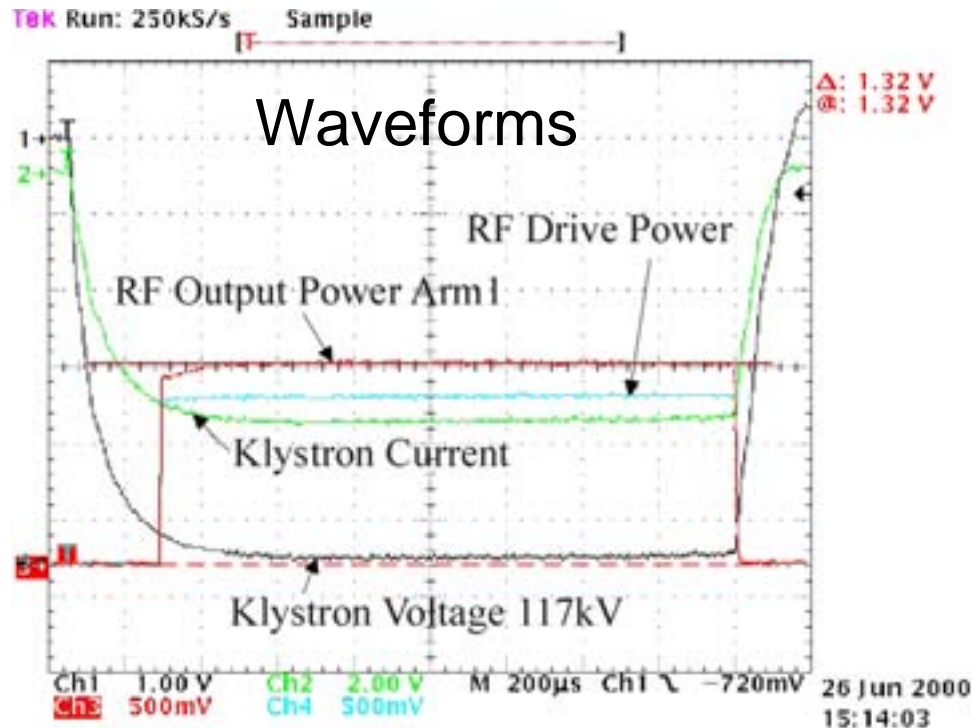
for the RF groups at DESY Hamburg and  
Zeuthen

# Modulators

- Modulators must generate HV pulses up to 120kV and 140A, 1.57ms pulse length and 10Hz repetition rate (option 50Hz, keeping klystron average beam power <250kW)
- The top of the pulse must be flat within 1%
- The bouncer type modulator with its simple circuit diagram was chosen



# The FNAL Modulator



- 3 modulators have been developed, built and delivered to TTF by FNAL since 1994
- They are continuously in operation under different operation conditions



FNAL Modulator at TTF

# Industry made Modulator

- Industry made subunits (PPT, ABB, FUG, Poynting)
- Constant power power supply for suppression of 10Hz repetition rate disturbances in the mains
- Compact storage capacitor bank with self healing capacitors
- IGCT Stack (ABB); 7 IGCTs in series, 2 are redundant

HVPS and Pulse Forming Unit



IGCT Stack

# Industry made Modulator cont.

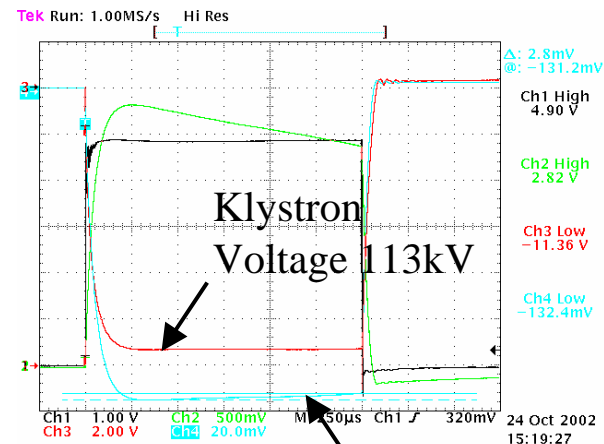
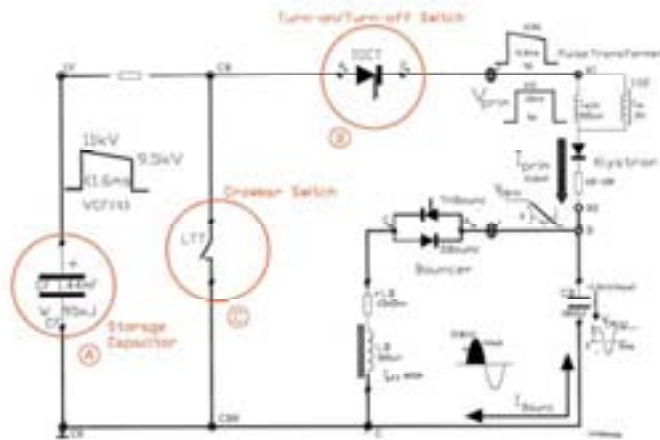
- Low leakage inductance pulse transformer (ABB)  $L < 200 \mu\text{H}$  resulting in shorter HV pulse rise time of  $< 200 \mu\text{s}$
- Light Triggered Thyristor crowbar avoiding mercury of ignitrons



Pulse Transformer



LTT



Klystron Current 132A

# Further required improvements of the industrial modulators

- Temperature problem of bounce coil at high rep. rate leading to RF pulse deterioration (RF Phase shift after some hours of operation)
- Temperature problem of IGCT Snubber (Resistors need water cooling)
- Breakdown of LTT crowbar (trigger circuit needs improved layout)
- Temperature problem of diodes and resistors parallel to series inductance (need improved cooling)
- EMI (some electrical connections must have lower inductance; cabinets need better shielding)

# Modulator Status

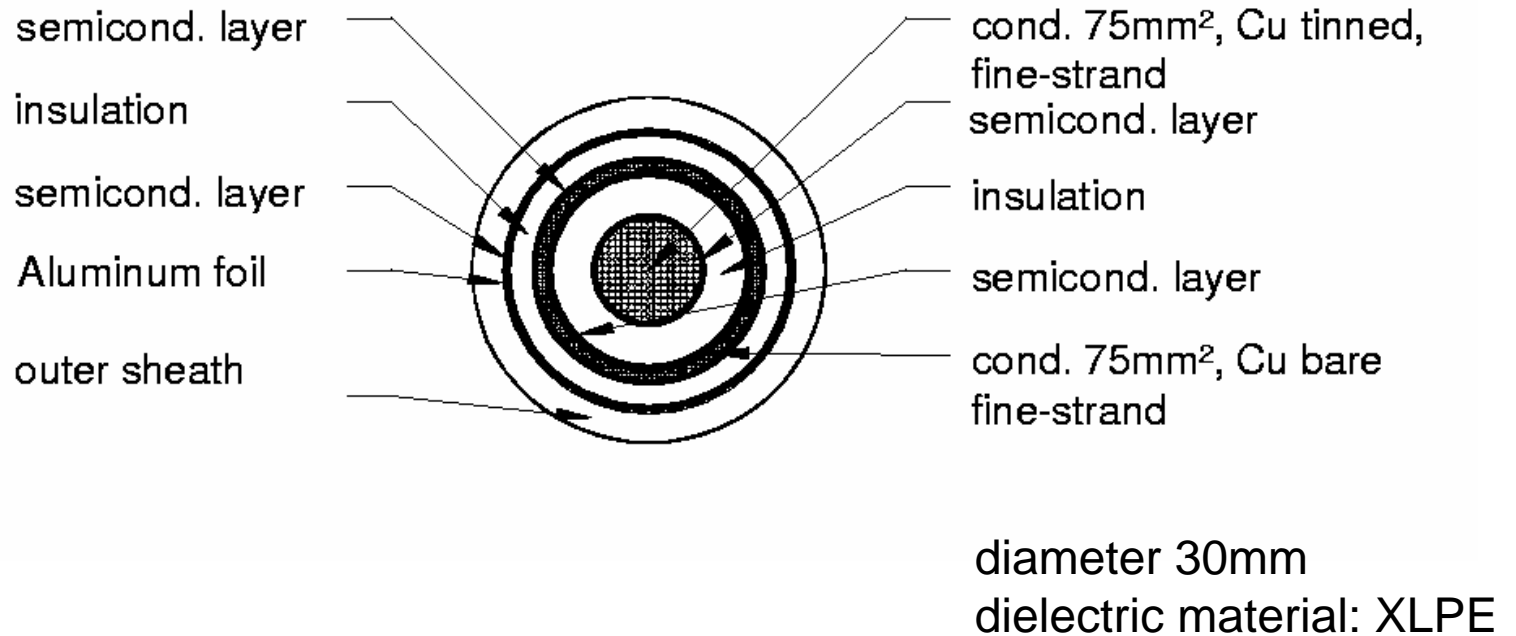
- 10 Modulators have been built, 3 by FNAL and 7 together with industry
- 8 modulators are in operation
- 10 years operation experience exists
- Many vendors for modulator components are available
- Most remaining problems related with cooling of components and EMI

# HV Pulse Cable

- Transmission of HV pulses (10kV, 1.6kA, 1.57ms, 10Hz (50Hz)) from the pulse generating unit (modulator hall) to the pulse transformer (accelerator tunnel)
- Maximum length 1.5km
- Impedance of 25 Ohms (4 cable in parallel will give 6.25 Ohms in total) to match the klystron impedance
- Triaxial construction (inner conductor at 10kV, middle conductor at 1kV, outer conductor at ground)



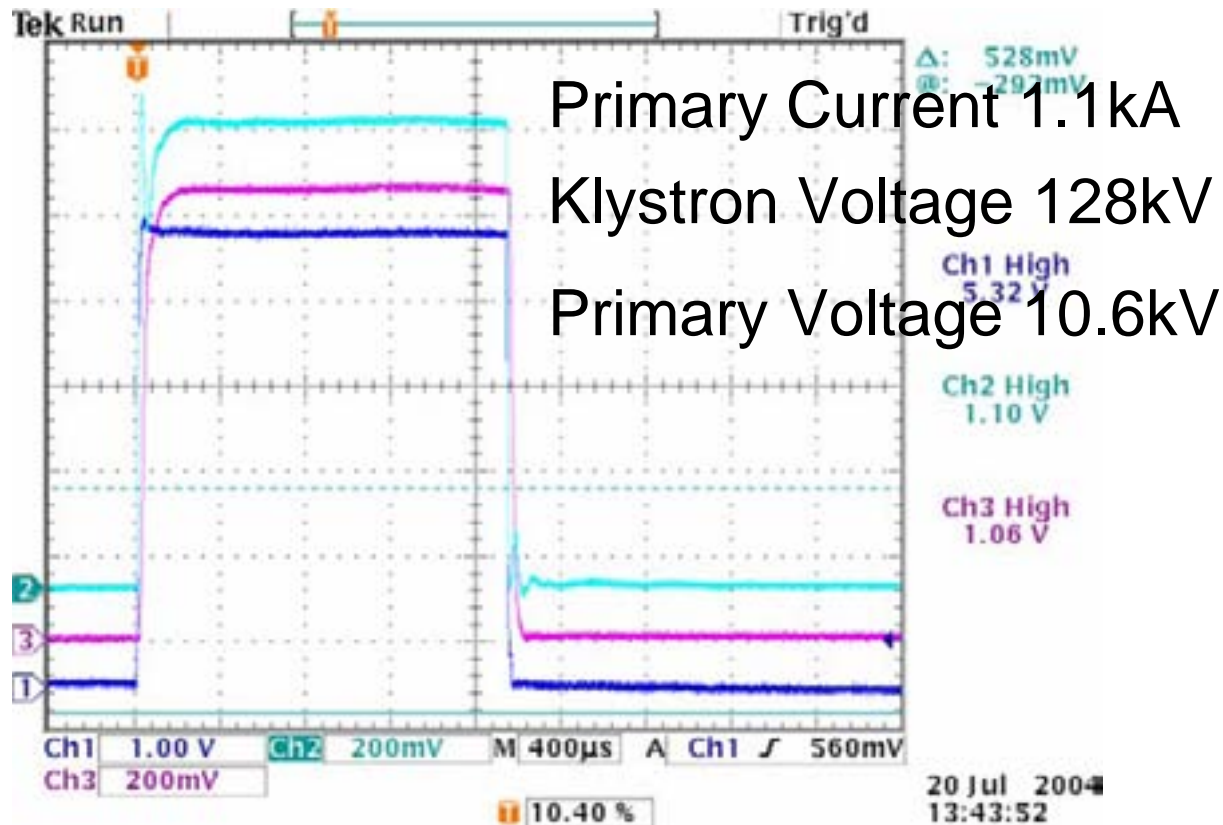
# HV Pulse Cable cont.



# HV Pulse Cable cont.

- Prototype cable has been delivered and first test has been successful
- Experience with similar cables in Europe and USA exists
- Minimum lifetime of the cables is  $10^{10}$  pulses = 111 years

# HV Pulse Cable cont.



Remaining problem: EMI needs investigation

# Future Plans

- Continue investigation of modulator operation at higher rep. rate up to 50Hz while keeping the klystron average input power constant (at DESY Zeuthen)
- Write specification of modulator/pulse transformer for hall/tunnel installation (modular layout with low MTTR, higher MTBF, low EMI) and find vendors responsible for entire modulator
- Goal: test 2-3 full prototypes within 2 years

# Planned Modulator Test Hall at DESY Zeuthen

