LMJ x-ray streak cameras vulnerability to EMP

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Estimated EMP during LMJ & PETAL shots

- **LMJ**, 176 laser beams, **gain shot**: 100 kV/m in the EC
  - ~10 kV/m in front of an inserted streak camera (SID ~ DIM)
- **PETAL**: 1 MV/m in the EC
  - ~100 kV/m in front of an inserted streak camera
- Orientation: ~isotrope in front of the XRSC (multiple reflections in the EC)
- Spectral width: several GHz
- Contemporary with the observed phenomenon, decay time: several 100s ns

**Electron optics**

- Voltage tolerances:
  - a few V on photocathode, F1, F2&O2
  - a few 100 mV on LQ
- Dimensions:
  - streak tube 48 cm long
  - electrodes a few cm long
CST Micro Wave Studio

EMP: intensity 100 kV/m at t₀, frequency 1, 5 and 10 GHz, damped sinus, planar wave

Simplification of XRSC geometry (suppression of complex photocathode holder)

Evaluation of E field intensity inside the air box, for a 5 GHz EMP:

- up to 5 kV/m inside the air box and the streak tube
- up to 3 kV/m inside the CCD camera
- < 1 kV/m in the electronics package only
FIRST SIMULATIONS

- CST Micro Wave Studio
- EMP: intensity 100 kV/m at t₀, frequency 1, 5 and 10 GHz, damped sinus, planar wave
- Simplification of XRSC geometry (suppression of complex photocathode holder)
- EM disturbance coupled to the cables:
  - common mode current up to 3A in cable shielding inside the air box, for a 5 GHz EMP
  - differential voltage up to 1.5 V for single shielded cables
  - differential voltage up to 15 mV for double shielded cables

common mode current, $E_{max}(5 \text{ GHz})$

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EMP COUPLING TO THE ELECTRODES

- EMP coupling to the streak tube

- EMP attenuation inside the streak tube

- ~ 30 V without µ-metal shielding
- ~ few V with µ-metal shielding

> voltage tolerances

<table>
<thead>
<tr>
<th>probe location and orientation</th>
<th>measured field</th>
</tr>
</thead>
<tbody>
<tr>
<td>① vertical H horizontal H</td>
<td>H₀</td>
</tr>
<tr>
<td>② vertical H horizontal H</td>
<td>H₀/3</td>
</tr>
<tr>
<td>③ horizontal H</td>
<td>H₀/3.7</td>
</tr>
<tr>
<td>④ horizontal H</td>
<td>H₀/20</td>
</tr>
<tr>
<td>⑤ horizontal H</td>
<td>H₀/40</td>
</tr>
<tr>
<td>⑥ longitudinal H</td>
<td>H₀/30</td>
</tr>
</tbody>
</table>

difference due to geometry: grounded horizontal accelerating slit

mean value: homogeneization in the grounded cylinder
EMI SYNCHRONIZED WITH IMAGE ACQUISITION

Experimental setup

- UV laser pulse train
- Pulsed HV generator: rise time 100 ps, duration 30 ns
- Delay line
- Laser pickoff
- Oscilloscope
- Vacum chamber
- Streak camera
- Streak tube
- CCD camera
- Electronics package
- Pulsed EM field up to 40 kV/m

Results

- Temporal profiles
  - Normalized amplitude (AU)
  - Spatial effects in the temporal direction
  - Linear evolution of shift vs $E_0$
  - $E_0 = 1$ kV/m $\leftrightarrow$ 1 pixel (~1-25 ps) shift

- Mean temporal shift, 2 ns full scale (ps)
- $E_0$ vs $E_0$ (kV/m)

Graphs showing:

- Temporal shift of measured pulse, 2 ns full scale (ps)
- Pulse # vs $E_0$ (kV/m)
- $p$-rms
LMJ only

- DP4 (2016):
  behind DMX, at 11 m from the TCC, with 1 laser chain
  $\Rightarrow < 1 \text{ kV/m}$ 😊

- DP2 and DP6 (2017):
  inserted in an SID (~DIM), at 3.3 m from the TCC, with 2 laser chains
  $\Rightarrow < 1 \text{ kV/m}$ 😊

LMJ + PETAL

- First PETAL shots (2017):
  depending on the target geometry, estimated to:
  - $\sim 10 \text{ kV/m}$ behind DMX, at 11 m
    from the TCC $\Rightarrow > \text{XRSC tolerance}$ 😐
  - $\sim 30 \text{ kV/m}$ inserted in an SID, at 3.3 m
    from the TCC $\Rightarrow > \text{XRSC tolerance}$ 😐
FUTURE WORK

EM field measurements
- Currently being installed in the experience chamber + hall
- Measurements in early 2017

Streak camera and plasma diagnostic prospects
- **Evaluation** of microscope / spectrometer EM attenuation
- **Timing fiducial** to monitor the EM disturbance during a shot
- **Shielding**: grounded tubing of optical paths

Streak tube evolution
- Grounded grids welded over the openings of the front flange
- Replacement of the glass enveloppe by a metal enveloppe
- Possibly coaxial, HV hermetic feedthroughs on the streak tube enveloppe, to minimize the unshielded cable length
Measure of x-ray streak camera EM sensitivity

- Tolerance 1 kV/m in front of the photocathode ⇔ temporal deflection 1 pixel

Estimation of EM disturbance for an integrated XRSC

- LMJ only:
  - OK until 2 laser chains
- With PETAL:
  - NOK from the first shot

Planned actions

- Measurement of EMP in the experience chamber
- Streak tube shielding
- XRSC and plasma diagnostic shielding
- UV timing fiducial for XRSC

+ how did you solve this issue?