Investigation of Scintillation Screens for High Energetic Heavy Ion Beams at GSI

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Plan of talk

- Motivation
- Experimental setup
- Results
- Conclusion
Motivation and Beam parameters

Behavior of screens @ high energies
Profile reproduction, light output, Radiation hardness
To be investigated for FAIR

Experiments
- U @ 269 MeV/u
- $10^4$ to $10^9$ particles per pulse
- 1 m upstream of a Beam dump
- Current measurement-IC & SEM

SIS 18 features
- $200 \text{ MeV/u} < E < 3 \text{ GeV/u}$
- $(56 \% < \beta < 98 \%)$
- All ion species
- Up to $10^{11}$ particles per pulse
## Investigated Scintillators

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single crystal</td>
<td>$\text{CsI:Tl}$</td>
<td>Saint Gobain Crystal</td>
</tr>
<tr>
<td></td>
<td>$\text{YAG:Ce}$</td>
<td></td>
</tr>
<tr>
<td>Phosphor screen</td>
<td>$P43 (\text{Gd}_2\text{O}_2\text{S}:\text{Tb})$</td>
<td>Proxitronic</td>
</tr>
<tr>
<td>Glass</td>
<td>$\text{Quartz (Herasil 102)}$</td>
<td>Heraeus Quarzglas</td>
</tr>
<tr>
<td></td>
<td>$\text{Quartz:Ce (M382)}$</td>
<td></td>
</tr>
<tr>
<td>Ceramics</td>
<td>$\text{Al}_2\text{O}_3:\text{Cr}, \text{Al}_2\text{O}_3$</td>
<td>BCE Special Ceramics</td>
</tr>
<tr>
<td></td>
<td>$\text{ZrO}_2:\text{Mg (Z507)}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\text{ZrO}_2:\text{Y (Z700)}$</td>
<td></td>
</tr>
</tbody>
</table>

To compare imaging property of different materials
Scintillating effect of different screens

Al₂O₃  CsI:Tl  Chromox  P43
YAG:Ce  Herasil  Quartz:Ce  Z507

Camera: AVT Marlin F033C, picture at different current
Optical setup

**Camera**: AVT Marlin
- without IR cut filter
- VGA resolution
- Firewire interface
- Trigger mode
- Variable exposure time
- Variable gain settings
- Data acquisition-BeamView

**Lens system**: Pentax lens
- 16mm focal length
- Remote controlled iris
- Dynamic range of 4 orders of magnitude

Spectral sensitivity of CCD
Experimental Setup at HTP

Target ladder → 110 * 11.5 cm
Sample size → 5 to 8 cm diameter

Target ladder mounted on linear drive moved by a stepper motor

Energy loss per ion in scintillators
Minimum: 28 MeV/u (6.7 GeV)
Maximum: 54 MeV/u (13 GeV)
Data evaluation

CCD camera

Region of interest

- Projection
- Light output
- Beamwidth
- Higher statistical moments

Background picture before each pulse

Different algorithm for data evaluation → similar trend is observed
Results: light output

CsI:Tl and YAG:Ce shows the highest light output

Parameters:
U@ 269 MeV/u
$10^4$ to $10^9$ ppp
300 ms pulse length
Results: light output

CsI:Tl and YAG:Ce shows the highest light output
Phosphour screen took the 3rd place

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Al₂O₃ : Cr shows one order of magnitude more light than Al₂O₃

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Results: light output

CsI:Tl and YAG:Ce shows the highest light output
Phosphor screen took the 3rd place
Al₂O₃ : Cr shows one order of magnitude more light than Al₂O₃
Herasil gives the lowest light output

Parameters:
U@ 269 MeV/u
10⁴ to 10⁹ ppp
300 ms pulse length

Similar trend in another Beam time
**Results: Profile Reproduction**

**σ of a Gaussian fit**

CsI:Tl and YAG:Ce shows broad profile
P43, Al$_2$O$_3$:Cr, Al$_2$O$_3$→similar profile
Herasil→small profile→small width

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Kurtosis

Peakedness of the distribution

\[ K = \sum_{j=1}^{N} \frac{w_j \left( \frac{x_j - \bar{X}}{\sigma} \right)^4}{W} - 3 \]

Lower the kurtosis → platykurtic distribution

Herasil shows high values → leptokurtic distribution
Broad Beam Width

$\sigma$ of Gaussian fit

<table>
<thead>
<tr>
<th>Material</th>
<th>Beamwidth $\sigma$ (mm)</th>
<th>Number of particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>CsI:Tl</td>
<td>7.5</td>
<td>$10^8$</td>
</tr>
<tr>
<td>YAG:Ce</td>
<td>6.0</td>
<td>$10^7$</td>
</tr>
<tr>
<td>ZrO$_2$:Mg</td>
<td>5.5</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Herasil</td>
<td>4.0</td>
<td>$10^5$</td>
</tr>
</tbody>
</table>

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Scintillation screens for high energetic heavy ion beams  
14.02.2011
Strange behaviour

CsI:Tl and YAG:Ce shows relatively broad beam profile

Reason → attributed to

Reflection from backside

Absorption and Re-emission

Herasil being a glass material does not show this effect!

Has to be investigated further
Conclusion

Light output

• CsI:Tl, YAG:Ce, P43, Al₂O₃:Cr, Al₂O₃, Herasil shows linear light output
• Al₂O₃:Cr shows an order of magnitude more light than Al₂O₃
• Herasil gives the low light yield but linear
• Z507 seems to get saturated at higher intensities

Beam width

• CsI:Tl gives the largest while herasil gives smallest beamwidth
• P43, Al₂O₃:Cr, Al₂O₃ gives a comparable result—difference less than 7%
• Broadening of profile at higher intensities for some samples
Future work

- Various Ion Beams, Different energies
- Spectroscopic investigation
- Investigation of radiation damage in materials