Emission is complicated: the beauty of resonant inelastic light scattering
- *in the lab with Aron*

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“when can you start at Columbia - in 3 months or sooner?”

... the way my journey with Aron started

„Werner – I would like to do a postdoc abroad. Do you where I could go?“

Werner Wegscheider: „I could write all of them an email“

Aron: „Ursula, when can you start?“

Your husband is a physicist as well? – we need to find another position!”

Your husband is a physicist as well? – we need to find another position!”
“Aron, what are these signatures in emission spectra?”

“… PL is complicated”
"the strength and beauty of RILS on collective excitations"

\[ I(E, q_0) \propto \int f(q, q_0) \rho(E, q) dq \]

line shape function

\[ f(q, q_0) = \text{Lorentzian with HWHM: } q_b = 0.145 \]

mode response function:

\[ \rho(q, q_0) = \frac{\Gamma/2}{(E - E(q)^2 + \Gamma^2} \]

calculated wave vector dispersion \( E(q) \)

Theroy J. Jain

UW et al. PRL 107, 066804 (2011)
“running on sugar”
dark, because it is healthier – but not too dark 😊
Transforming dark swiss chocolate in PRL and other paper

“running on sugar”
Circularly polarization PL on gated MoS$_2$ monolayers

Depolarization mechanism at low doping?

“PL is complicated”

“… I am fully convinced and telling it to my students”

B. Miller, UW et al. APL. 106, 122103 (2015)
Circularly polarized Raman

**Non-resonant**

\[ \langle \sigma^+ | \sigma^- \rangle \]

\[ \langle \sigma^+ | \sigma^+ \rangle \]

\[ \langle \sigma^+ | \sigma^- \rangle \]

**Resonant**

632nm

\[ \langle A, B \rangle \]

---

\[ I \propto |e_s \cdot R \cdot e_i|^2 \]

\[ E'_{DP} = \begin{pmatrix} 0 & d & 0 \\ d & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \]

\[ A'_{DP} = \begin{pmatrix} a & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & b \end{pmatrix} \]

\[ E_{Fröhlich} = \begin{pmatrix} c & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & c \end{pmatrix} \]

→ circular cross-polarized

→ circular co-polarized

Fröhlich coupling

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Fröhlich exciton-phonon coupling

LO mode, polar 1s exciton

Fröhlich exciton-LO phonon coupling
(long range → macroscopic E-field)

Fröhlich coupling

\[ E_{\text{Fröhlich}} = \begin{pmatrix} c & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & c \end{pmatrix} \]

→ circular co-polarized

“Insights from (R)ILS”

Circularly polarized Raman

Folie in Ursprungsform bringen über Menü:
Start > Folien > Zurücksetzen

Hilfslinien anzeigen über Menü:
Ansicht > Anzeigen > Haken bei Führungslinien setzen

Wechsel des Folienlayouts im Menü über:
Start > Folien > Layout

Datumsfeld dient als Kopfzeile!

Kopfzeile anpassen:
Einfügen > Text > Kopf- und Fußzeile

Fröhlich exciton-phonon interaction suppressed by doping and depolarization mechanism.

Fröhlich exciton-phonon coupling

Fröhlich exciton-LO phonon coupling (long range → macroscopic E-field)

Exciton-enhanced Raman scattering by optical phonons

E. Burstein++, D. L. Mills†
Physics Department, University of California, Irvine, California

and

A. Pinczuk* and S. Ushioda*
Materials Department and Laboratory for Research on the Structure of Matter,
University of Pennsylvania, Philadelphia, Pennsylvania
(Received 16 September 1968)

The theory of exciton-enhanced Raman scattering is formulated in terms of the scattering of polaritons by optical phonons via the exciton part of the coupled modes. The expression for the exciton contribution to the scattering tensor is given, within a constant factor, in terms of the same parameters that determine the exciton contribution to the frequency-dependent dielectric constant. The theory also provides a new mechanism for the exciton contribution to the electro-optic effect.


It’s an old paper. We published a lot.

“Aron, what about this Fröhlich coupling?”
soccer, nuts, fun, tears and the question: “would you like to do a different project”
in the lab with Aron
soccer, nuts, fun, tears and lots of data
farewell celebrations from Columbia
Going out for group lunch or dinner
Coming back to NYC after 2 years immediately feeling welcome – thank you Aron and Glady’s

Little lion - best fried and companion of Barbara from the first minute – reminds us every day on Aron and Glady’s.
True mentorship and support during a “lock-down” Zoom session between Pinczuk and Wurstbauer groups.
True mentorship and support
during a “lock-down” Zoom session between Pinczuk and Wurstbauer groups
True mentorship and support during a “lock-down” Zoom session between Pinczuk and Wurstbauer groups

<table>
<thead>
<tr>
<th>Optical Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>clear aperture [mm]</td>
<td>4.7</td>
</tr>
<tr>
<td>focal length [mm]</td>
<td>2.87</td>
</tr>
<tr>
<td>numerical aperture (NA)</td>
<td>0.62</td>
</tr>
<tr>
<td>working distance</td>
<td>0.65 mm (1.40 mm)</td>
</tr>
</tbody>
</table>

Spectral Performance

AR coating (> 80% transmission) [nm] | 400 _ 1000 |

achromatic range (m) < +/- delta m [nml] | 565 _ 7701 |
Listen Ebene erhöhen 
erhöhen 
Listenebene verringern 
verringern

Wechsel der Textebene

im Menü über:

Start > Absatz > Listenebene erhöhen/verringern

Folie in Ursprungsform

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Fußzeile anpassen:

Einfügen > Text > Kopf- und Fußzeile

Wechsel des Folienlayouts

im Menü über:

Start > Folien > Layout

Datumsfeld dient

als Kopfzeile!

Kopfzeile anpassen:

Einfügen > Text > Kopf- und Fußzeile

Hier steht der Titel der Präsentation
fingerprints for collective excitation in van der Waals materials from mK-RILS

Reconstructed MoSe$_2$/WSe$_2$ with degenerate IX ensemble

CrSBr – a layered magnetic semiconductor

T = 4K ; B = 0T

T = 4K ; B = 5T

Aron, thank you very much for teaching me and sharing the beauty of RILS – and for the continued support!
Dear Ursula,

Many thanks for email and season's greeting. You have a lovely family. You all look great!

This year my holiday season is complicated. This fall our teaching has been in-person. I am now very busy with calculating final grades and with related activities. In carrying out this work I neglected conventional contacts of the season.

Gladys and I hope you had a wonderful Christmas and wish you a very happy new year.

We got the NSF grant and Ziyu started training in the operation of the Kelvinox dil-fridge.

Shall we set up a Zoom session to talk about physics?

With kind regards,

Aron
Aron, I feel very privileged that I am part of your „science family“ . I truly acknowledge your great mentorship through all the years. Without you I would not be were I am now and I would not be the person I am today.

Thank you!