A Vision for Future Synthesis Facilities

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An organizational & technical perspective

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An outside & out-of-the box perspective on the US

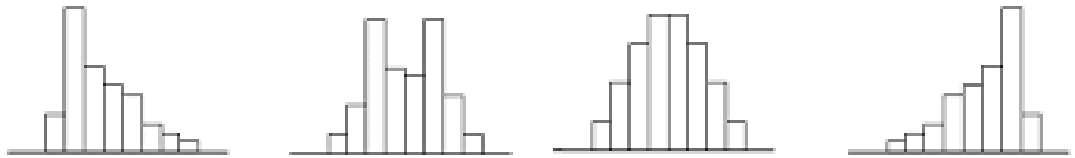
- inside knowledge, gaining an outside perspective
- impressive success stories: So, are we heading in the right direction?
- provocative, simplified picture: dramatic change in the boundary conditions
  - invest of universities in expensive capital equipment to hire junior faculty in synthesis
  - need to see the ROI eventually (foreseeable within tenure track time)
  - limits the junior faculty choices; clamps them down to a narrow selection of materials
  - synthesis = starting material + substrates + operation cost + materials characterization
  - state-of-the-art materials characterization facilities at universities are enablers; also potential impeders and educational stoppers

Can funding agencies empower PIs and provide leverage?

- negotiate reduced overhead rates operating/bringing MIPs online (IUCRC)

What is the right model for future synthesis facilities?

- operational approach:
  - decentralized vs. centralized
  - university-based vs. national-lab-based facility
- funding model:
  - permanent core budget vs. ‘volatile’ 3rd party funding
  - university, funding agency, private sector, industry
- competition, diversity, transfer:
  - number and size of facilities
  - national vs. international
  - fundamental vs. applied



What is our (inter)national strategy to build a robust and competitive synthesis infrastructure addressing future synthesis needs?

The pillars of science funding in Germany

GDP into research (3.13%)

GWK (Joint Science Conference)

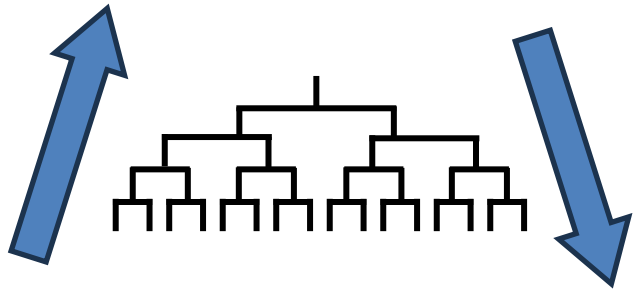
universities
(state funded, private)

non-university institutions
(state and federally funded)

1.399 B€	4.106 B€	1.016 B€	2.146 B€
Leibniz Association	HELMHOLTZ GEMEINSCHAFT	Fraunhofer	Max-Planck
core budget	43 % state 57 % federal	10 % state 90 % federal	20 % state 80 % federal	43 % state 57 % federal

https://www.wissenschaftsrat.de/download/2024/Basisdaten.pdf?__blob=publicationFile&v=5

Governance structure of non-university institutions



Association

bottom-up, grass roots

Society

top-down, centralized

unique academic selling point

large research infrastructure

applied

basic

e.g.:

Leibniz Association

currently 95 research institutions
with unique core competences

How to operate in a centralized non-university setting?

funding eligibility

NKS EVF DEUTSCHE KONTAKTSTELLE FÜR DEN EUROPÄISCHEN VERTEIDIGUNGSFONDS

erc

DFG Deutsche Forschungsgemeinschaft German Research Foundation

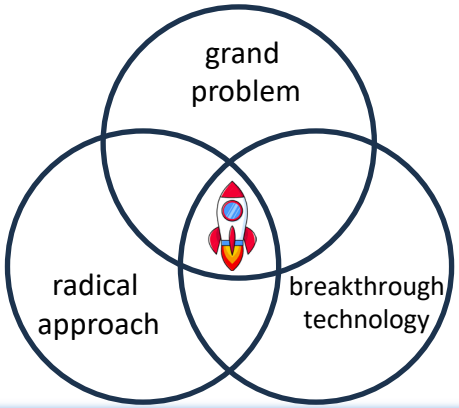
Federal Ministry of Education and Research

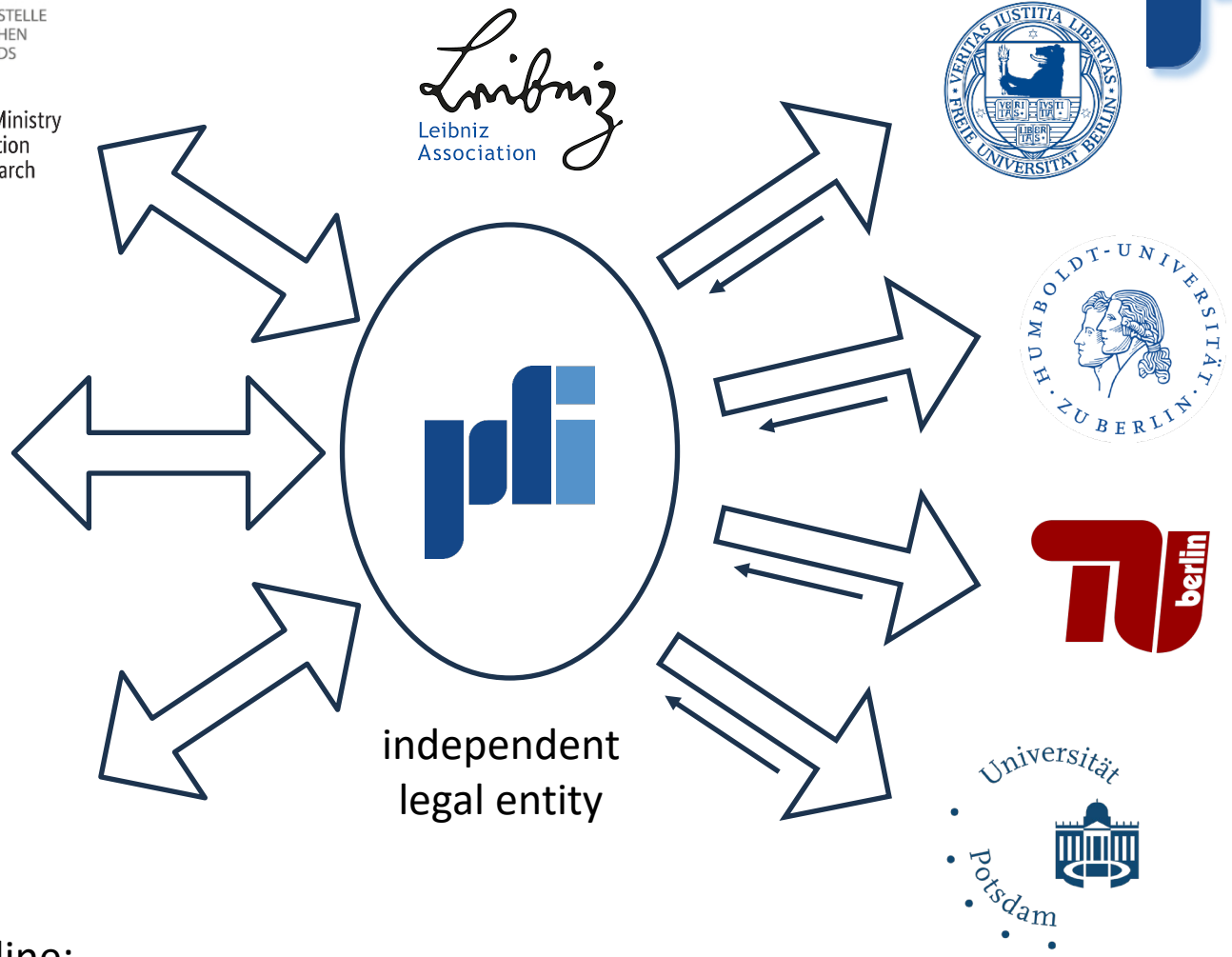
negotiate collaborative research agreements

amu OSRAM BOSCH Infineon technologies AIRBUS HELMHOLTZ GEMEINSCHAFT

flexibility to craft our own funding scheme

PDI's materials moonshot program:

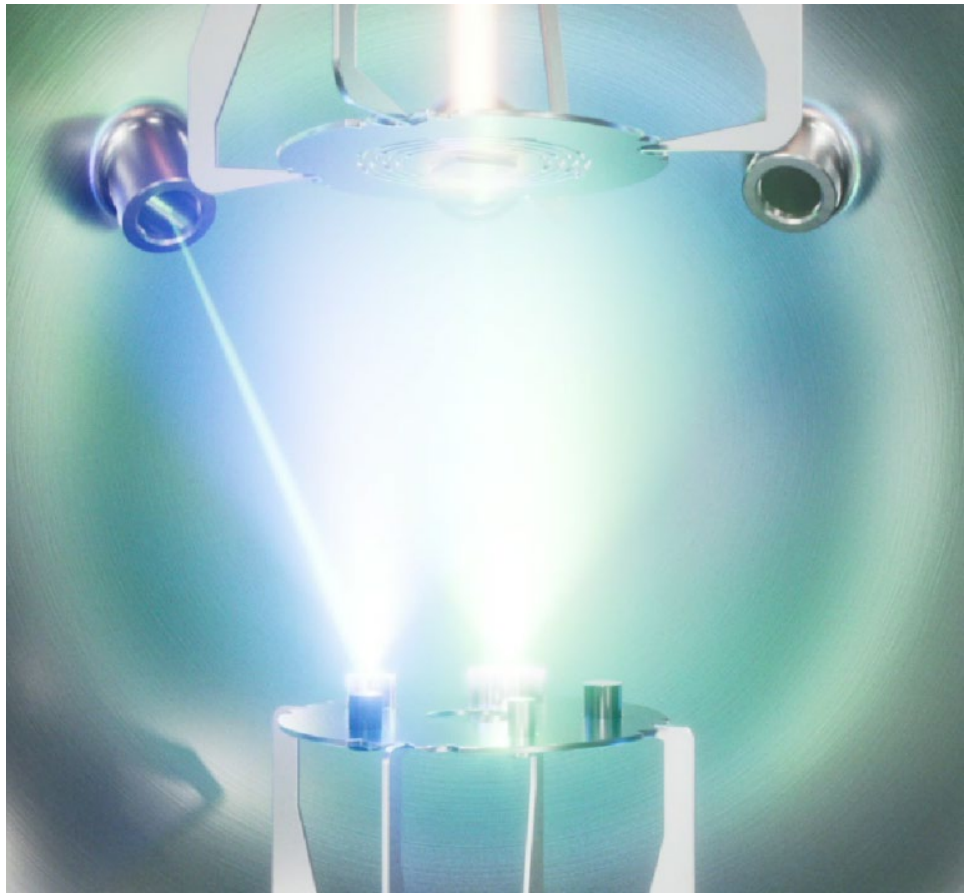




timeline:
write it in a day, hear back in a week, start within a month for one year

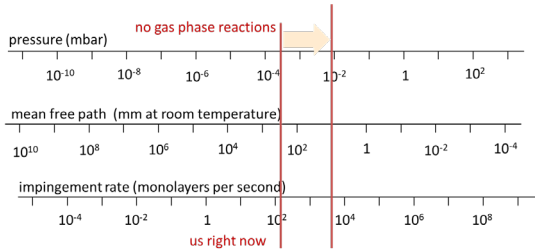
Empower future synthesis developments: Be disruptive!

Thermal laser epitaxy



https://epiray.de/science/

- lifting synthesis constraints:
  - non-equilibrium to enable kinetics
  - temperature constraint
  - pressure constraint



- many challenges:
  - flux uniformity and stability
  - (elemental) sources become a study object

- rapid maturation:
  - need to be synthesis community effort
  - build an international center of competence
  - invite international experts with diverse skill set

Some final thoughts

- Future challenges in synthesis can only be tackled by a diverse team (experiment, theory, data science,…)
- Large synthesis centers in academic settings are therefore key (MIPs, Materials Foundry,..)
- Thermodynamics and Kinetics is the foundation
  - start with your phase diagram, make them synthesis friendly
  - expand experimentally accessible growth conditions
- utilize AI/AE/ML to speed up building a robust database
- improve quality/quantity of in-operando experimental data
  - RHEED, and? (**flux**: QCM, AAS, line-of-sight QMS, **temperature**: IR cameras, **structure**: GI-XRD, LEIS, **spectroscopy**: SE, XRF, ARPES?)

Metal-Jet
X-ray source