Technische Universität Braunschweig

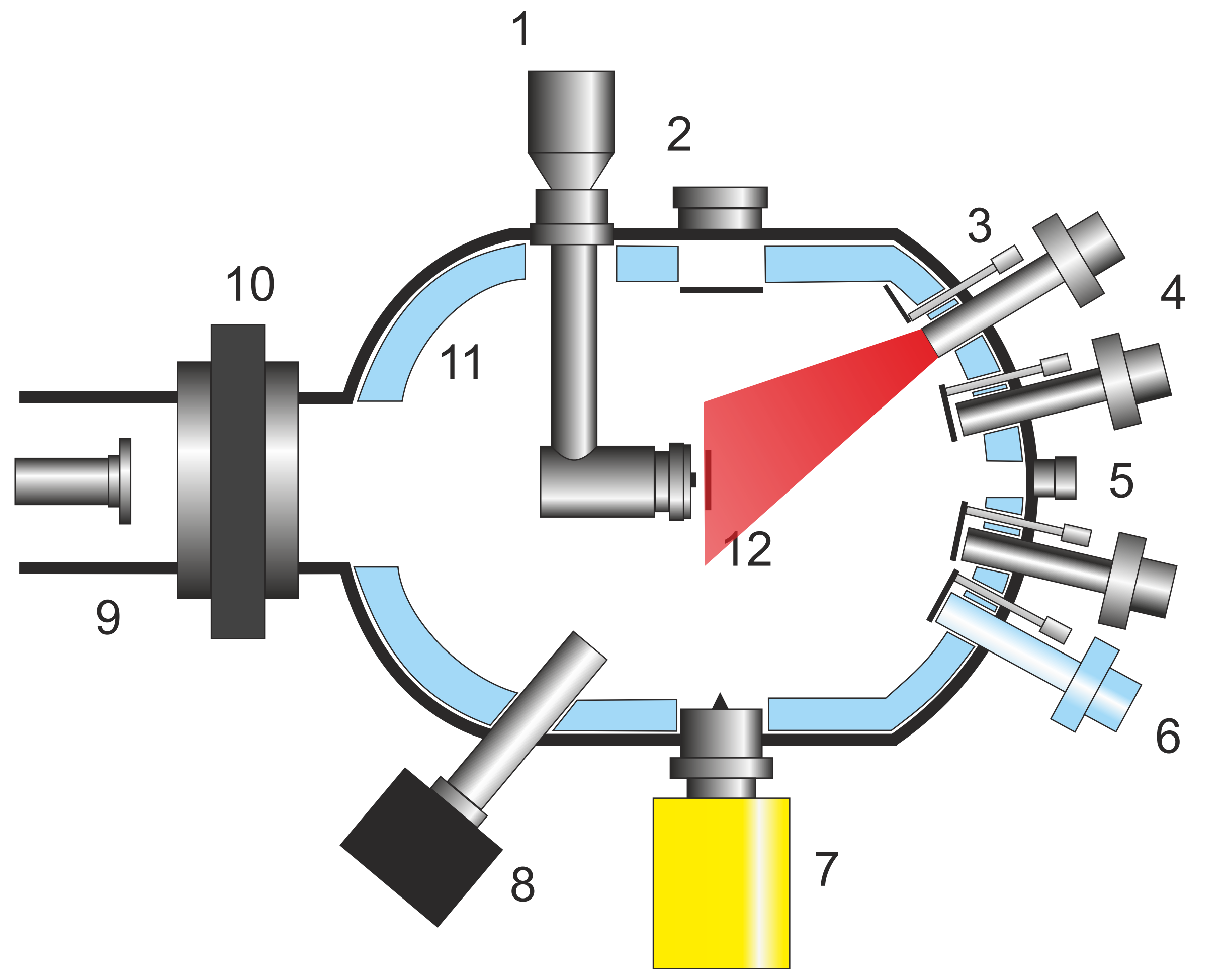
Institut für Angewandte Physik

MOLECULAR BEAM EPITAXY

Institute of Applied Physics, Technische Universität Braunschweig, 38106 Braunschweig, Germany

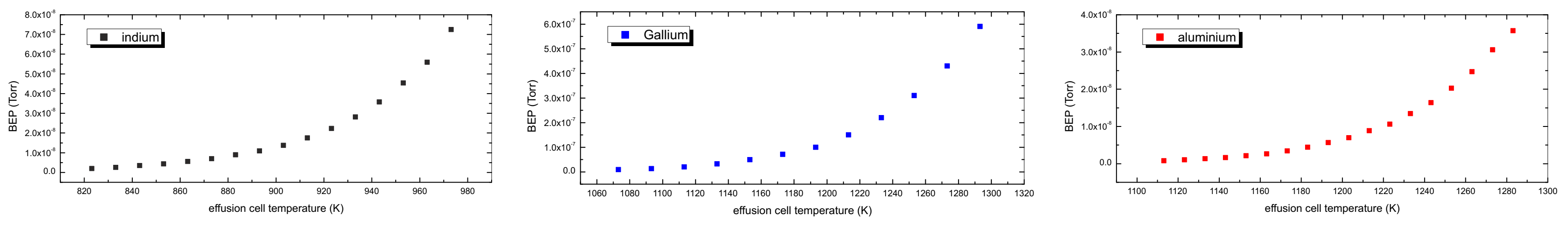
MBE machine

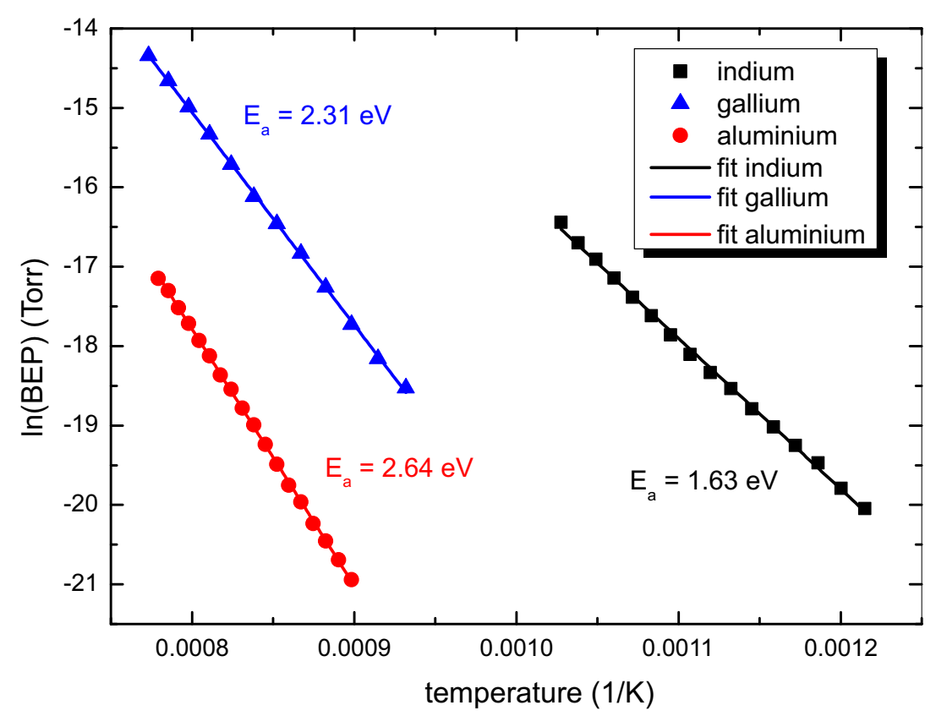
1 manipulator
2 RHEED screen
3 shutter
4 effusion cells
5 pyrometer window
6 plasma source
7 RHEED gun
8 quadrupol
9 transfer rod
10 valve
11 LN2 shrouds
12 substrate



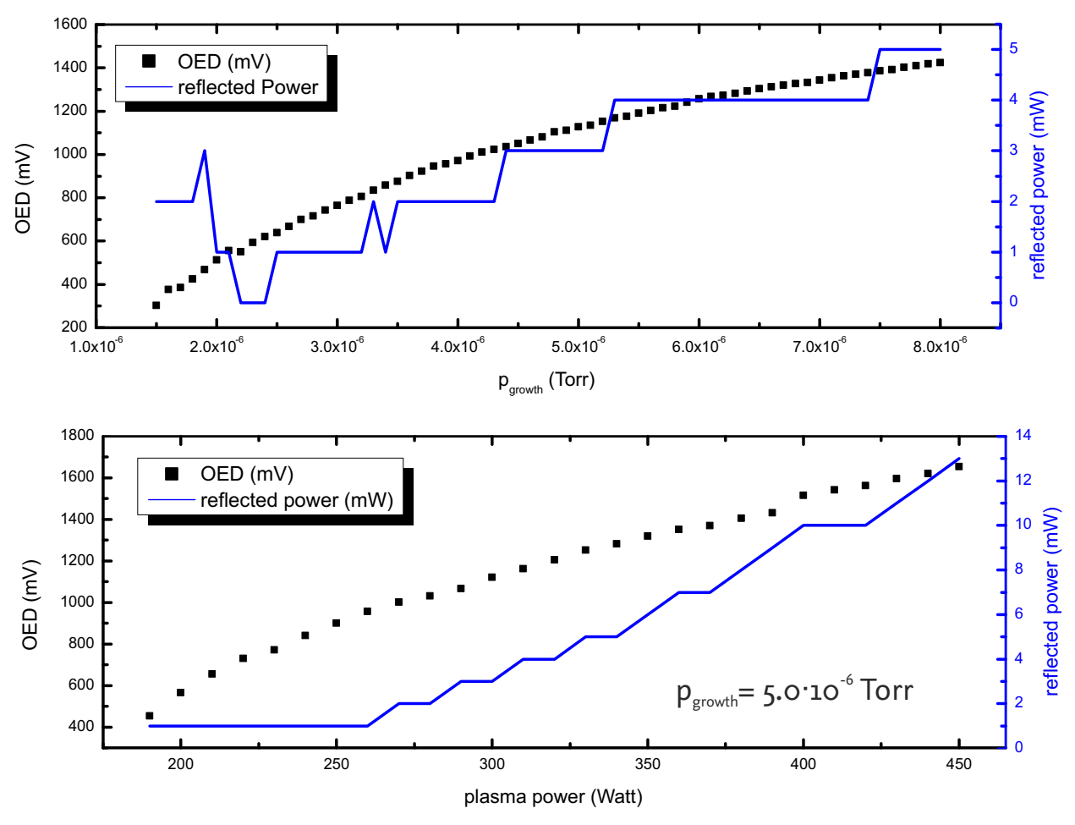
RF-MBE Basics:

beam equivalent pressure (BEP)





- is controled by effusion cell temperature
- temperature to BEP ratio is material specific
- BEP gives the group-III flux
- Arrhenius dependence for different crucible temperatures
- activation energies: $E_a(In) = 1.63$ eV
  $E_a(Ga) = 2.31$ eV
  $E_a(Al) = 2.64$ eV



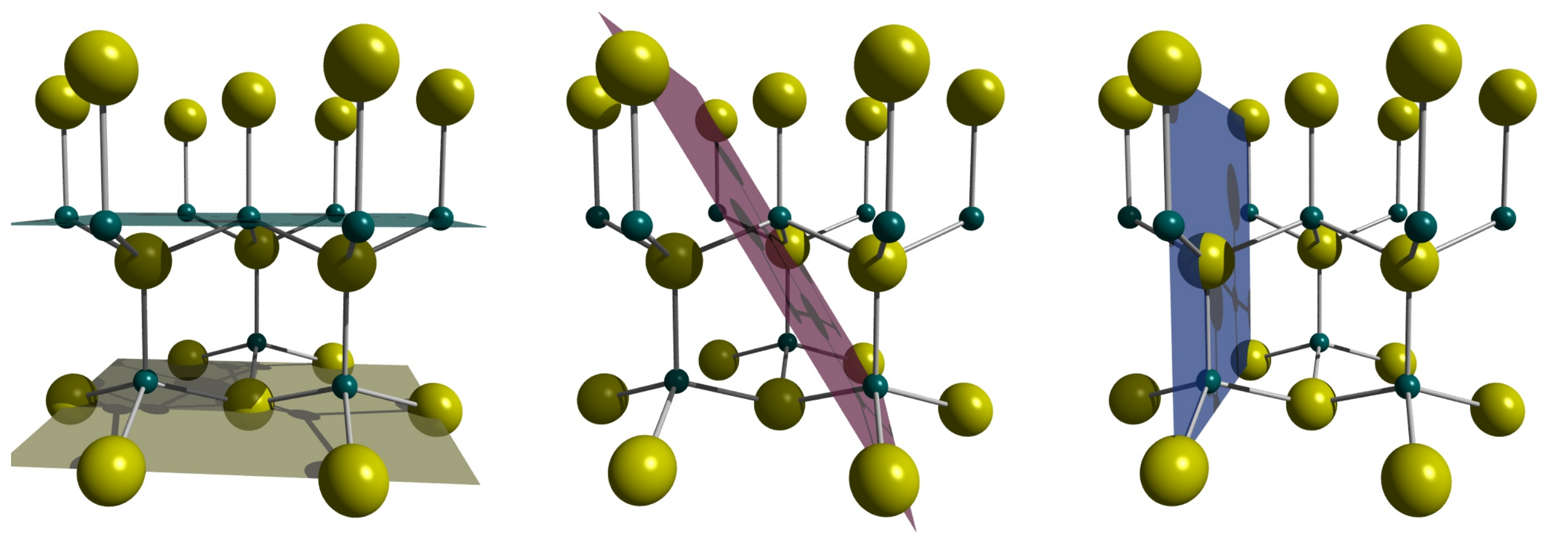
optical emission monitor (OEM)

- OEM: directly proportional to amount of excited nitrogen
- dependent on plasma power and on partial pressure

Material system: III-nitrides

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub						

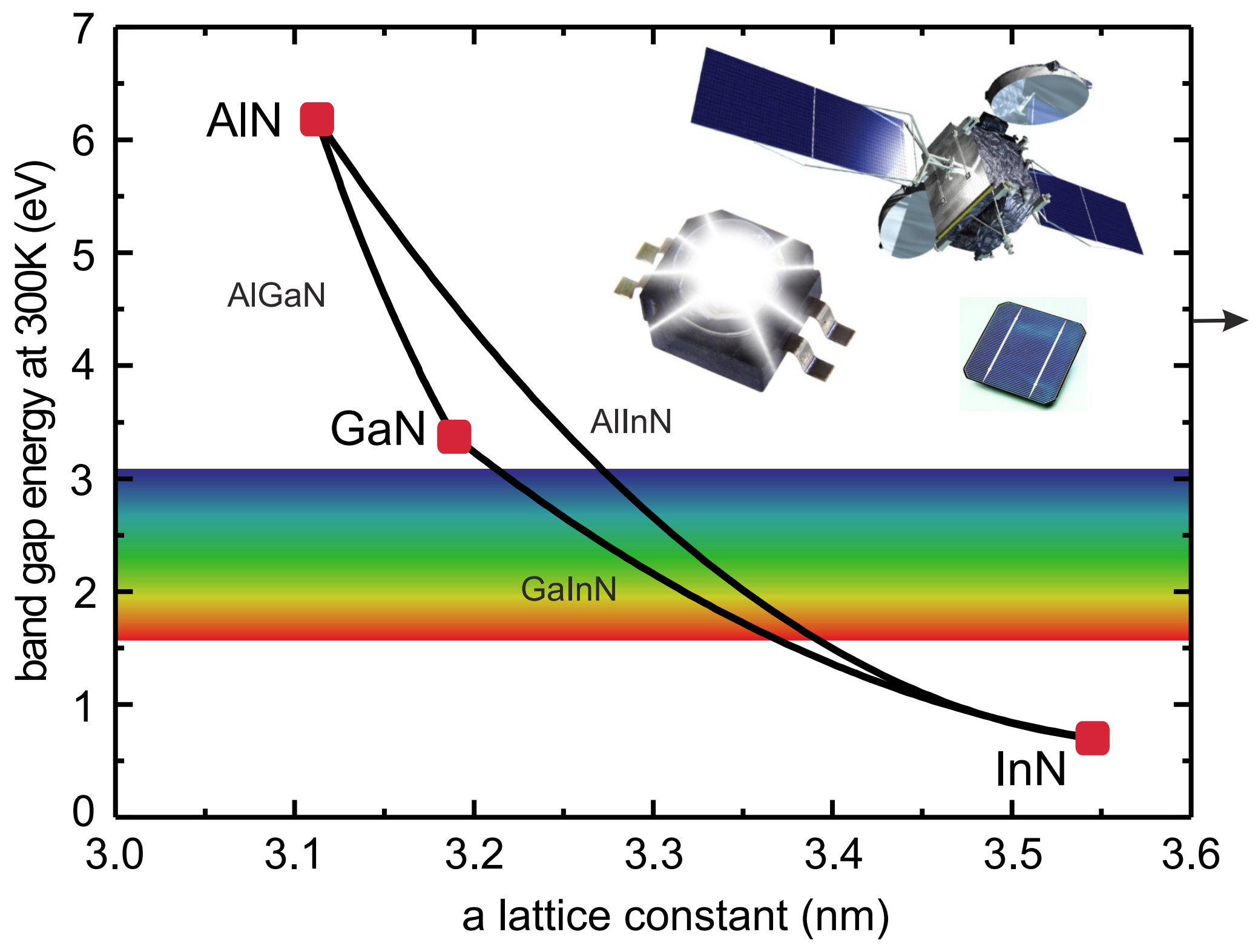
- AlN, GaN, InN and ternary alloys
- basically wurtzite structure
- direct band gap
- depending on crystal direction different polarization effects


polar semipolar nonpolar

Problems and difficulties:

- lack of suitable substrates, most commonly used is sapphire
- large missmatch in thermal expansion coefficients as well as lattice constants
- very different bond strength to nitrogen ⟶ different decomposition temperatures

Advantages

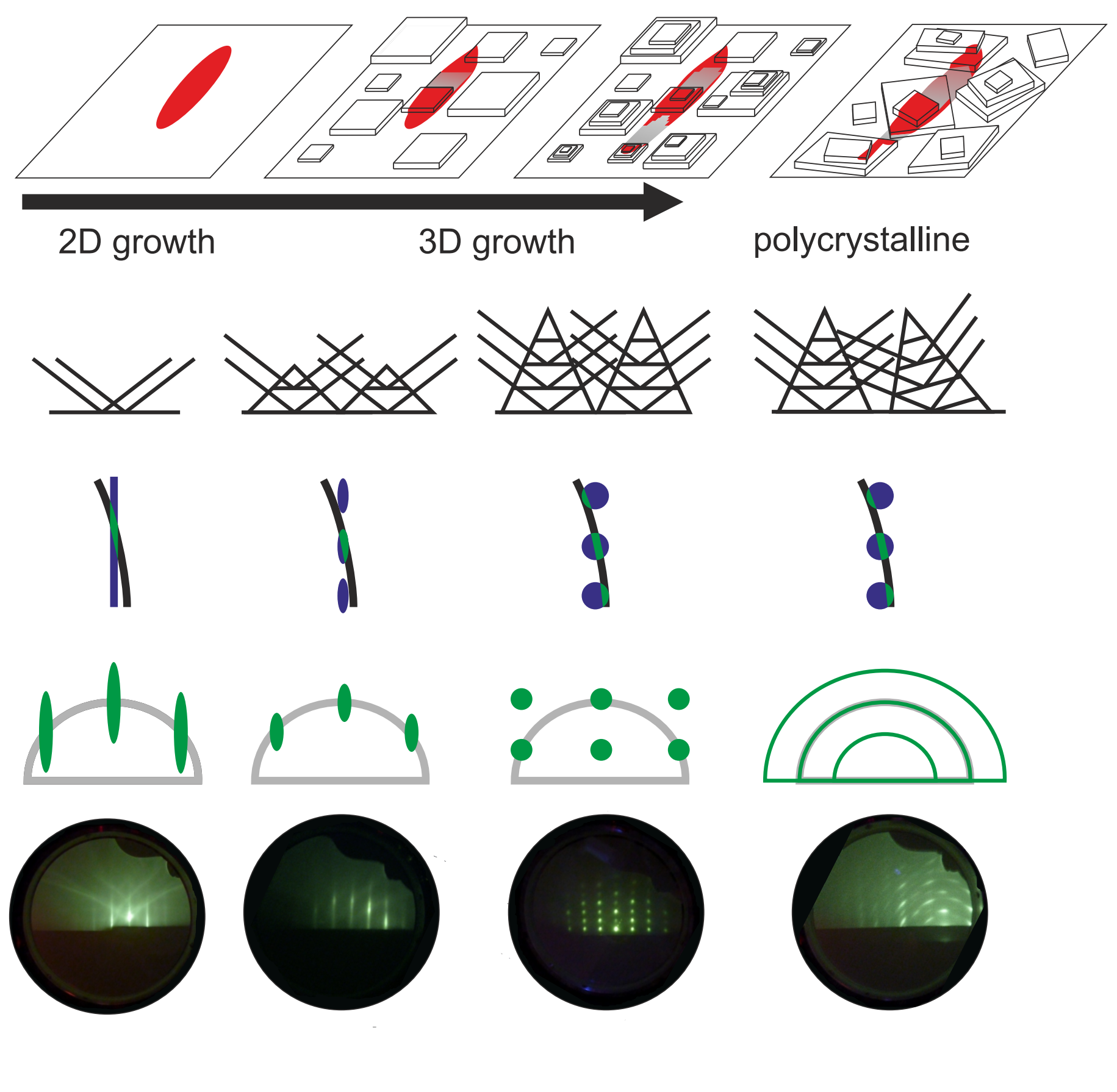


- huge band gap range from 0.7 eV for InN over 3.4 eV for GaN to 6.2 eV for AlN ternary alloys:
  tuning the band gap in a spectral range of infrared to ultraviolet
- high carrier mobilities
- high radiation resistance

large interest for optoelectronic devices

In situ characterization

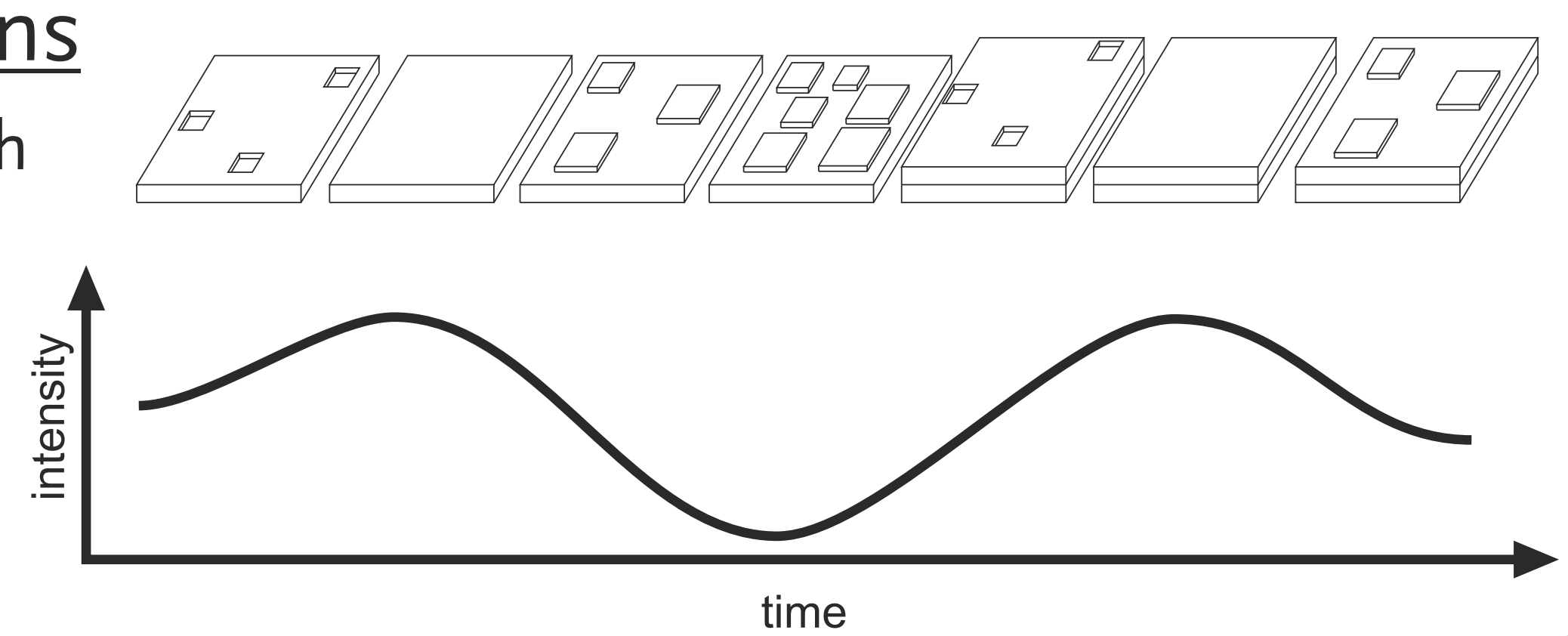
Reflection high energy electron diffraction (RHEED)



- in-situ growth monitoring
- after being diffracted at the sample surface the electrons hit a fluorescence screen which gives a diffraction pattern
- surface sensitive (small incident angle)
- pattern characteristics gives:
  - horizontal spacing of the rods or dots is direct proportional to reciprocal lattice constants
  - intensity and formation (roughness (qualitatively))
  - orientation (reconstruction)

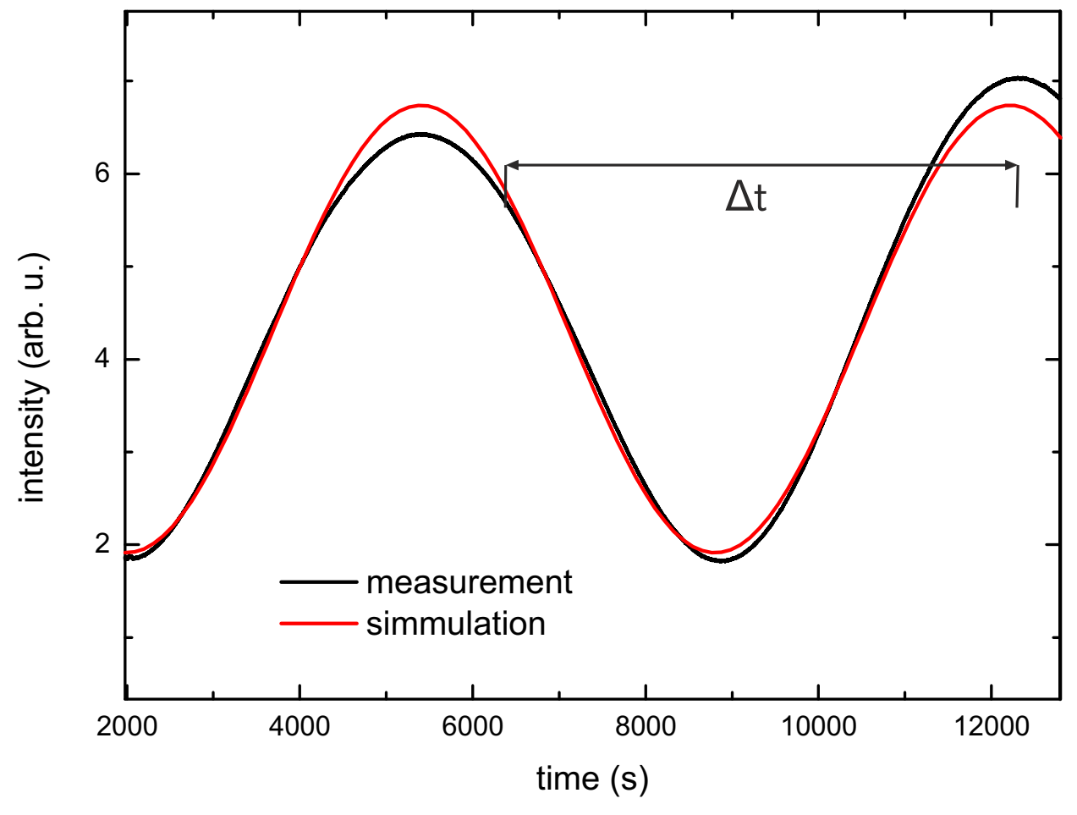
RHEED intensity oszillations

- one periode equivalent to growth time of one monolayer
- gives growthrates very exactly
- only visible at two dimensional growth mode

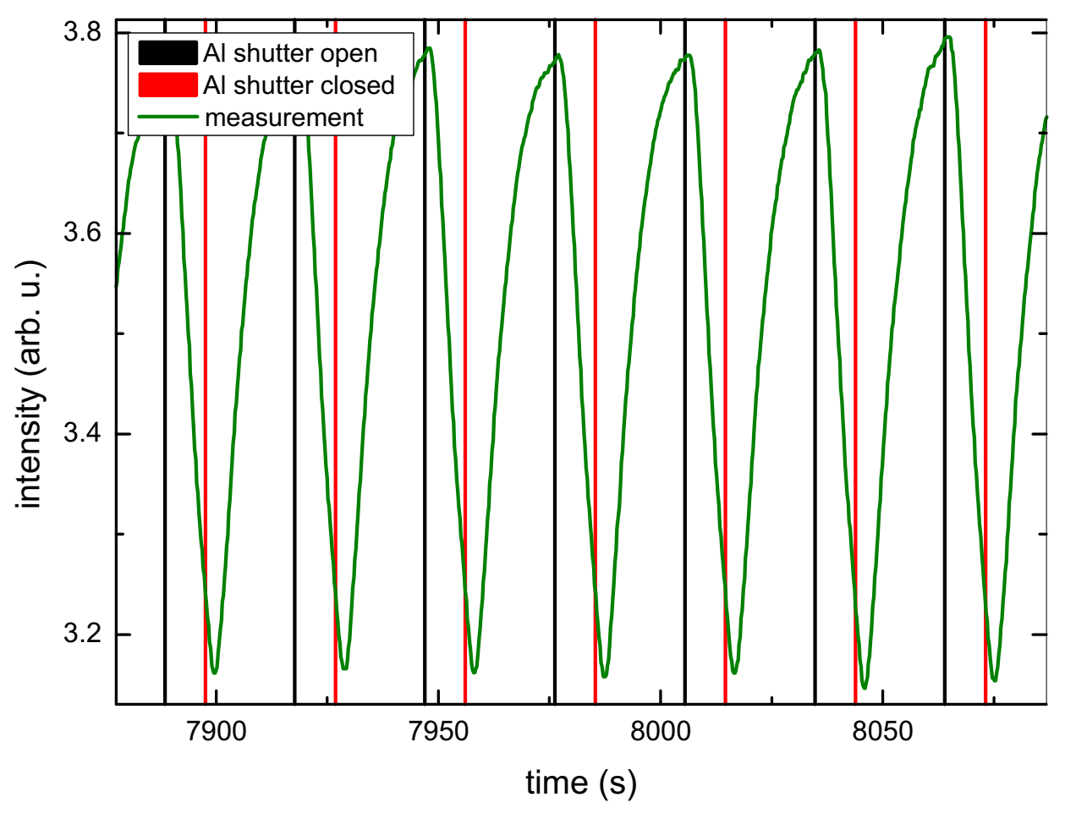


In-situ reflectrometry

- the light of a 636 nm laser diode is directed in a 75° angle on the sample surface
- reflected light is caught by a photo diode equipped with an infrared filter
- estimation of the growth rate taking the sinus shape into account
- monitoring the periods for pulsed growth



~300 nm thick AlN layer on a GaN template



pulsed growth of AlN on a GaN template

contact person: Dipl. Phys. Andreas Kraus

literature:

Material system: Nitride semiconductors: handbook on materials and devices,
Pierre Ruterana, Martin Albrecht, Jörg Neugebauer

MBE: Molecular beam epitaxy: fundamentals and current status,
Marian A. Herman, Helmut Sitter

RHEED: Reflection High Energy Electron Diffraction,
Ayahiko Ichimiya and Philip I. Cohen