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UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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WORKSHOP ON SPACE PHYSICS:
"Materials in Micorgravity"
27 February - 17 March 1989

"Development of an Advanced Vapour Growth Facility

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Please note: These are preliminary notes intended for internal distribution only.

Conditions of vapor growth depend on material

- low-temperatures (70-170°C): α-HgI_2 ; organic electrooptic materials
- medium temperatures ($T \leq 1050°C$): materials: II-VI ; III-V (GaAs etc); IV-VI (IR)

Sequential development of the two parts of the facility

1. Low temperature range

Advantages → direct observation due to transparent furnace

↓

Exact measurement of the growth rate (CCD-video) as a function of supersaturation, temperature and impurities concentration

Extremely important to understand growth mechanisms and optimize crystal perfection

TECHNICAL REQUIREMENTS OF ■ GROWTH APPARATUS

NASA Apparatus Viewgraph van d. Berg et al

Advantage: Crystal in the middle. Away from the walls.

Theory predicts at the walls solutal convection

Excellent electrical properties of the α-HgI_2 crystal grown in space support this argument. Viewgraph van d. Berg et al Slide "

Optimization of the space facility

NASA Vapor Growth Facility

- First to understand the importance of vapor growth under microgravity.
- Had to follow the hard constraints for the first Spacelab-flights.
- Manual control concept.
- Principal Investigator = Payload Specialist excellent combination.

New Facility

- Advantage, longer flight times (Eureca, Space Station)

↓

Large single crystals for applications
Due to mechanical distortion, microgravity beneficial.

↓

With increasing growth time, the average mass uptake increases strongly

CORNERSTONES OF FUTURE VAPOR GROWTH EXPERIMENTS IN SPACE

1. Purification and Standardization of the starting material.

↓

collaboration with EG+G in the IML-Program

2. Measurement of the diffusion coefficient of this material in space.

↓

GAS Experiment

3. Growth facility design
   a) Volume of ≈ 1lt for large crystals
   b) Expanding cooling surface
   c) Additional Reservoirs for partial pressure control of excess components and impurities
   d) Diagnostics

→

d) Diagnostics (in situ)

- Interface Temperature Measurement
  Combined with diffusion coeffic. under µg ↓

MONITORING ACTUAL SUPERSATURATION

- Monitoring of growth rate in various crystallographic orientations (µ resolution)

↓ Possible collaboration with other groups in several flights.

Use of know-how from this facility to develop a high temperature facility (≈1100°C) for vapor growth of GaAs and other II-VI and III-V compounds for substrates.

Characteristic Elements of the new facility

1. Higher stoichiometry
   Reservoirs of the elements to establish certain Hg/I ratio
2. Optimized Geometry
   Start with VAN DEN BERG - NASA Aspect Ratio
3. Measure + Control Supersaturation
   Pyrometric measurement of the crystal SURFACE TEMPERATURE
4. Decrease Thermal Stresses
   Microprocessor controlled expanding cooling surface (same rate as lateral crystal growth)
   COAXIAL COOLING RINGS
   Accuracy 1/100 °C
5. Growth Rate Measurement
   2 Video Cameras; Stepwise scanning
   Mathematic reconstruction of the position of various edges; Comp. Assisted Tests

kg 154 days
kg 78 days
kg 62 days

~300 g/day 9th month
170 g/day 120th
100 g/day 90th day
60 g/day 63rd day
24 g/day 44th day

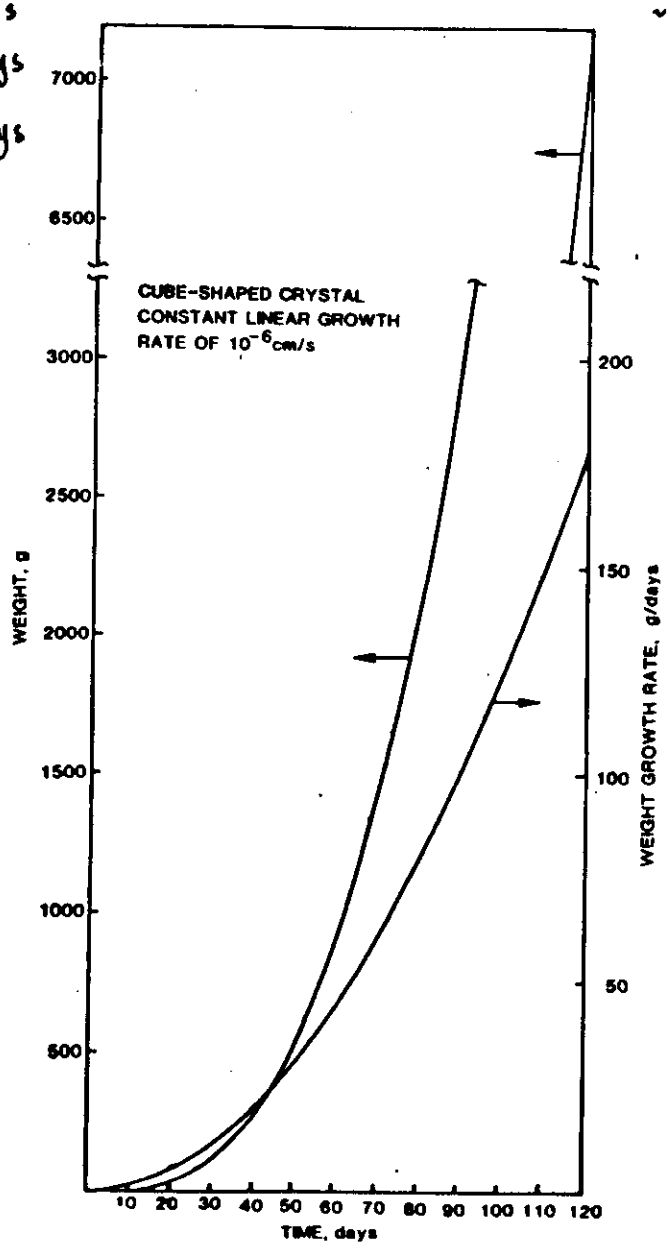

Fig.11.1 Increase of weight and weight growth rate with growth time for a cube-shaped α-HgI_2 crystal growing with the constant linear growth rate of $1 \cdot 10^{-6}$cm/s.

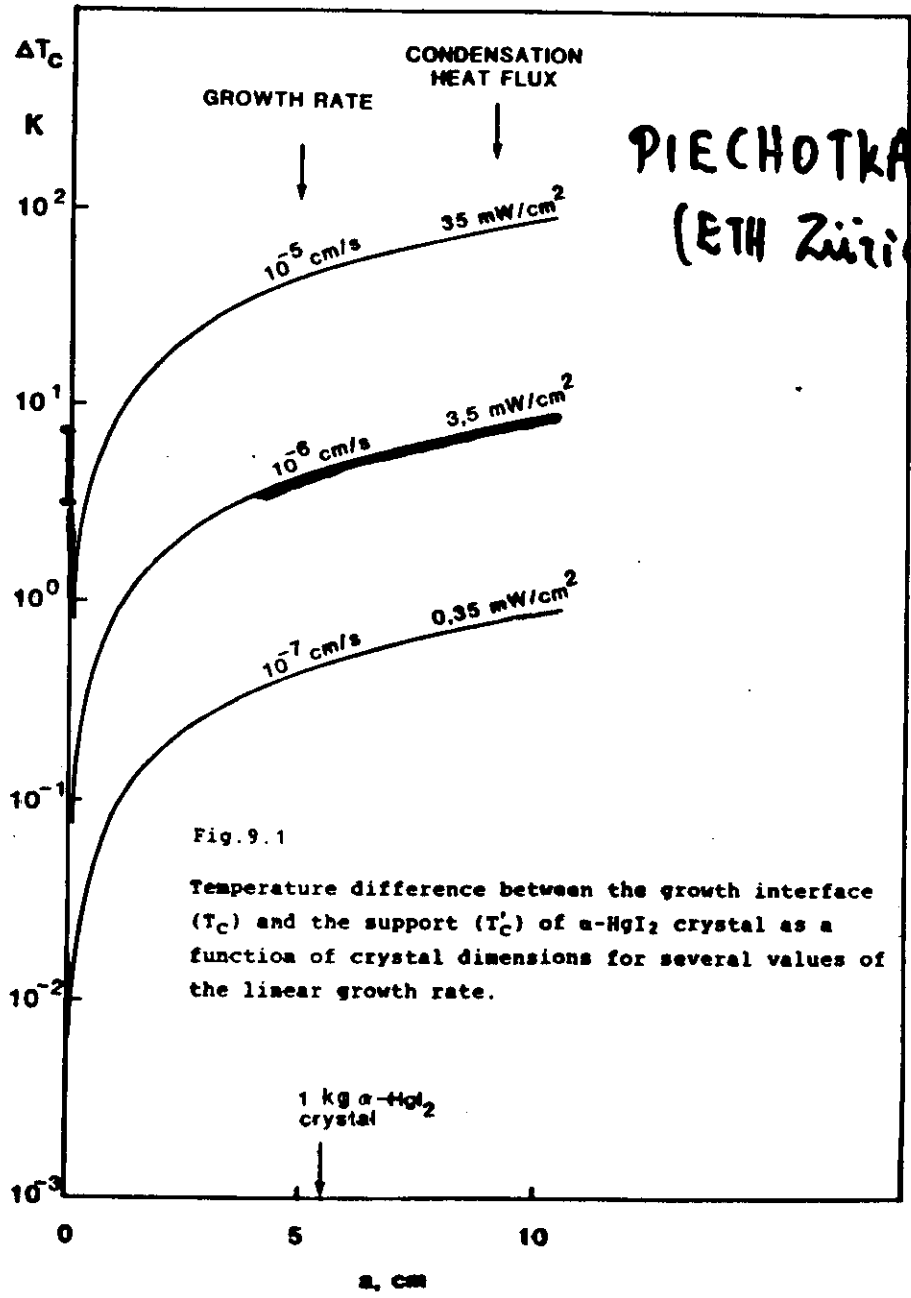

Fig.9.1

Temperature difference between the growth interface (T_c) and the support (T_c') of α-HgI_2 crystal as a function of crystal dimensions for several values of the linear growth rate.

PIECHOTKA
(ETH Zürich)

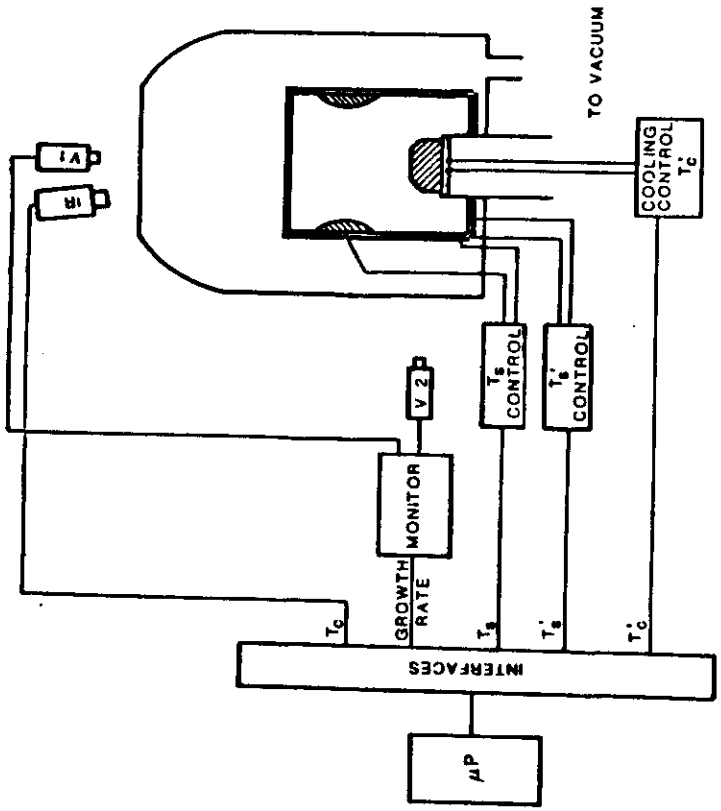

Fig.9.2 Schematic diagram of the growth chamber and control units for vapor growth at low temperatures (80 - 170°C), suitable for the growth of α-HgI_2 crystals, organic materials etc. For explanations see text.

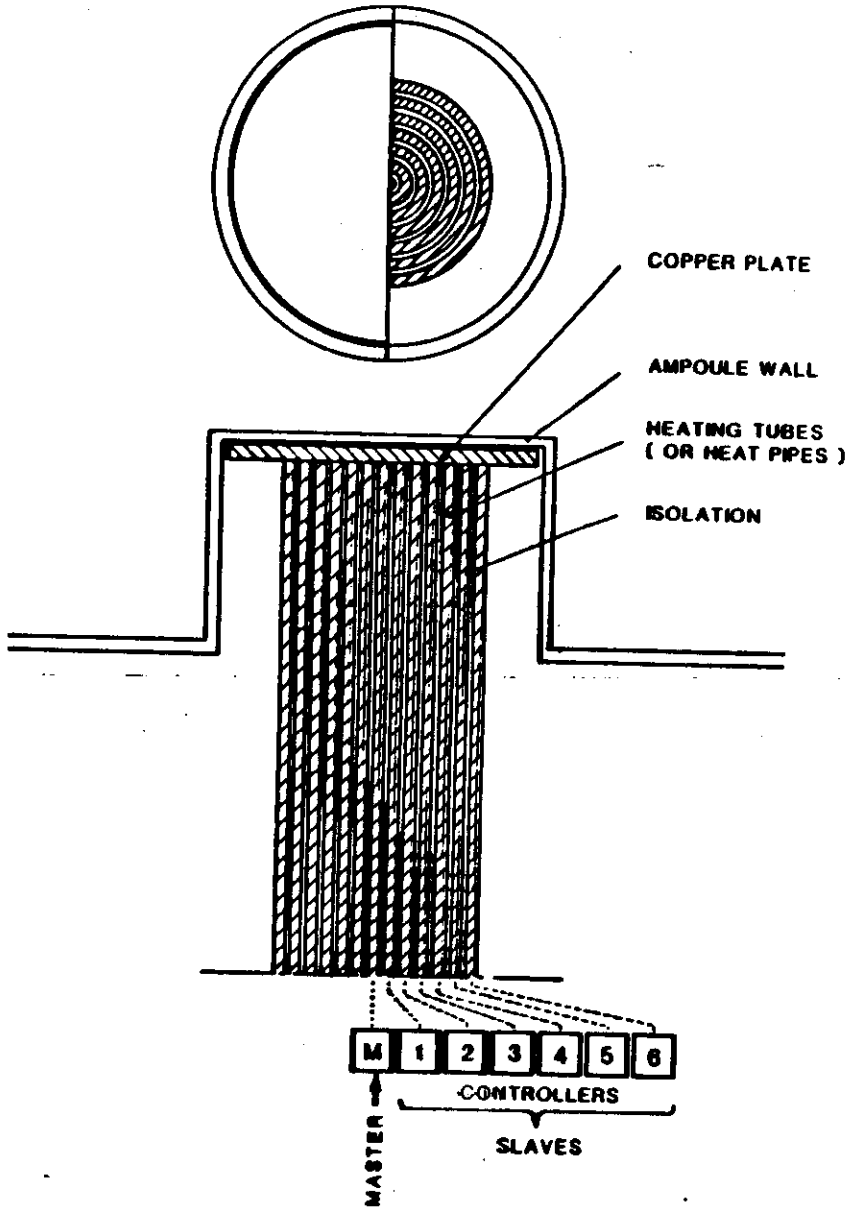

Fig.9.5 Possible configuration of concentric rings for cooling of the crystal.

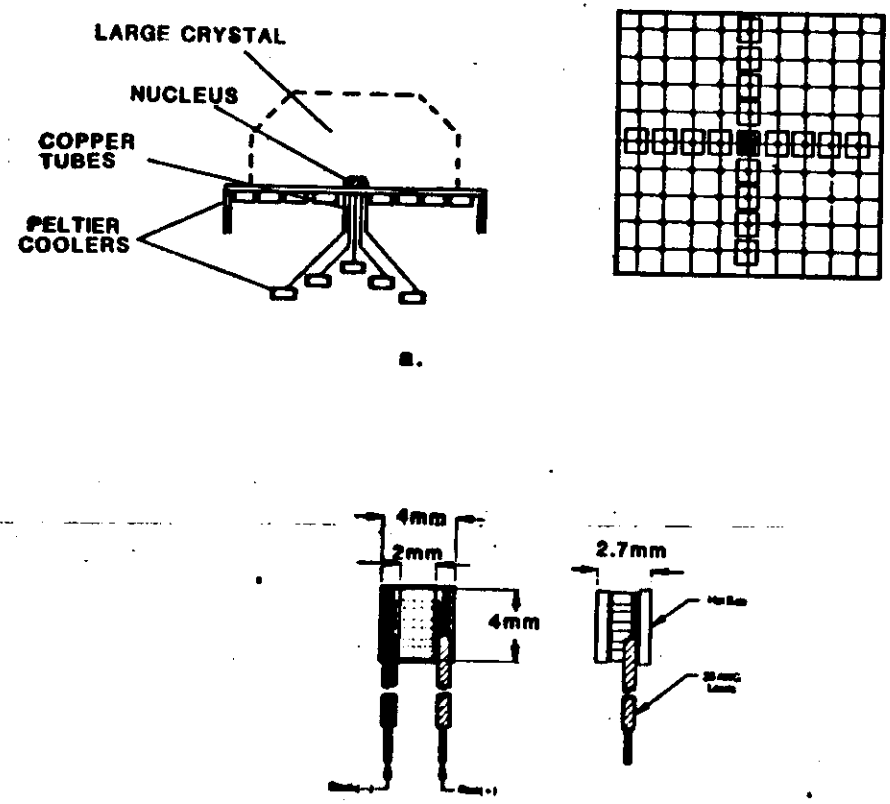

Fig.9.4 a) Possible configuration of the cooling array. It consists of 81 Peltier thermoelectric coolers connected in series forming five separately controlled concentric rings.
b) Elemental unit of the array. (After MIDLAND ROSS CORP., 1985).

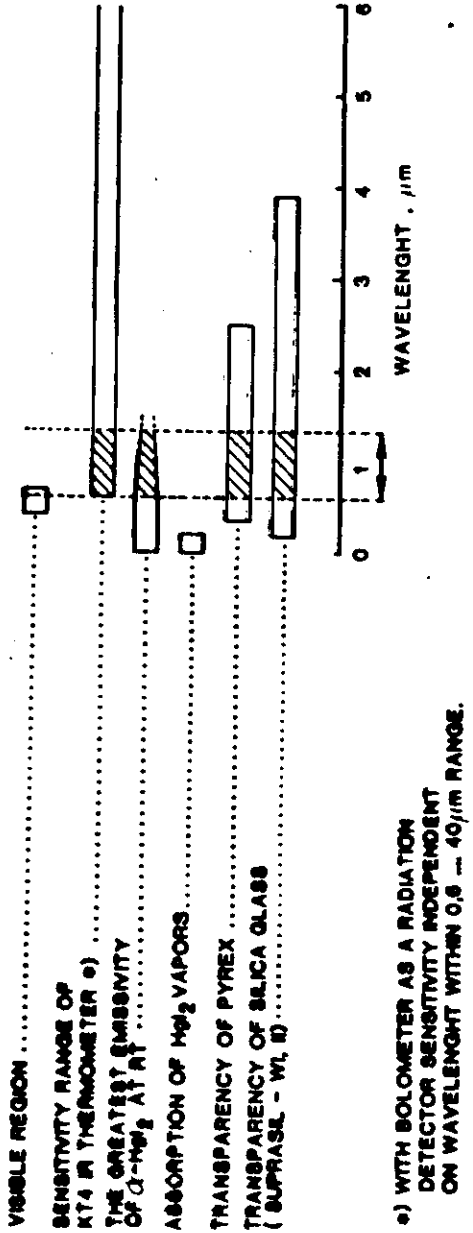

Fig.9.3 Spectral characteristics of the crystal, vapor and walls of the growth chamber for vapor growth of α-HgI_2 crystals (T=300 K).

The new growth facility
should fullfill following experimental
possibilities to INCREASE CRYSTAL PERFECTION

1. (Independent of design) →
   USE MATERIAL WITH HIGHER PURITY
   + STOICHIOMETRY

2. USE OPTIMIZED REACTOR GEOMETRY

3. DRIVE GROWTH WITH EXACTLY MEASURED
   AND DIRECTLY CONTROLLED SUPERSATURATION
   (Measure surface temperature to overcome the
   influence of the thermal resistivity of large crystals)

4 DECREASE THERMAL STRESSES IN THE CRYSTAL
   (microprocessor controlled, expanding, cooling
   surface)

5 HIGH RESOLUTION GROWTH RATE MEASUREMENT
   (for diagnostics of - growth mechanism
   - formation of defects