Multi-physics model for Thermal Management of packaged Mid-IR laser

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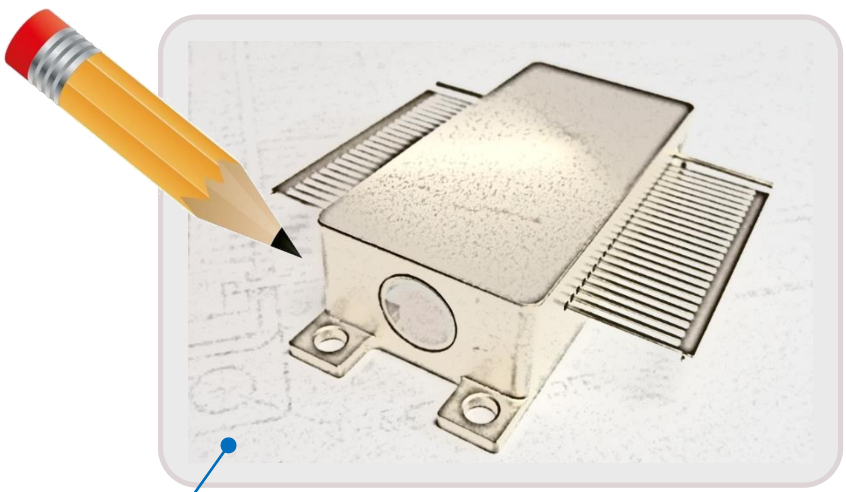

COMSOL CONFERENCE 2018 LAUSANNE

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MIRPHAB
CHEMICAL SENSING AND SPECTROSCOPY

Outline

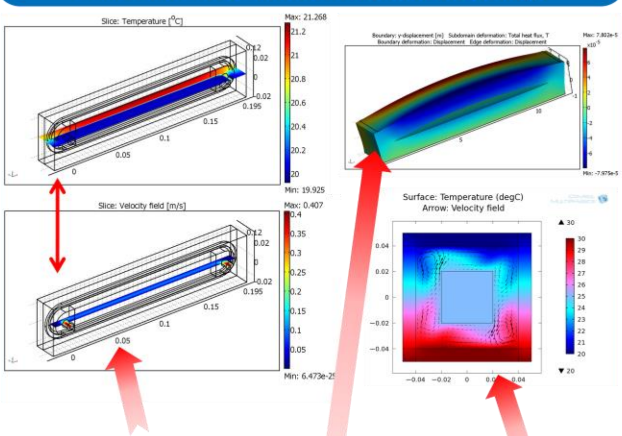
- Modeling @ CSEM (not exhaustive!)
- Mid-IR Laser thermal management and packaging considerations
- Multi-physics modeling challenges
- Selected simulation approach
- TEC model / Full Package model implementation and results
- Conclusions

And many other multi-physics simulations…

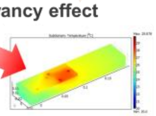
Comsol Modeling @ CSEM

- **Microfluidic modeling**
- **Optical field modeling**
- **Diffusion-driven physics modeling**
- **Thermal modeling**
- **Resistive path accurate calculation**

Thermo-fluid-mechanical modeling

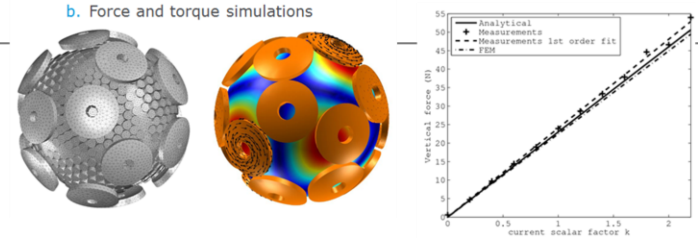


- Forced convection heat flow
- Nonlinear contacting plates thermal-induced bending
- Package cavity convection including gas buoyancy effect
- Thin thermal interfaces (TIMs) modeling
- Coupled or sequential simulations
- 2D & 3D models
- and more …



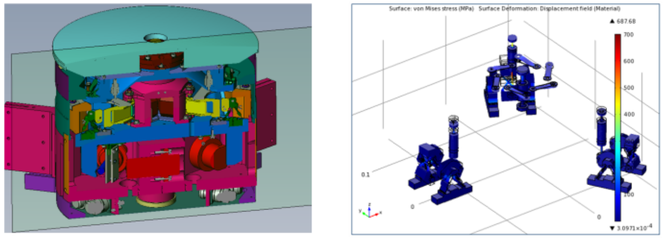
AC/DC electric and magnetic calculations

b. Force and torque simulations



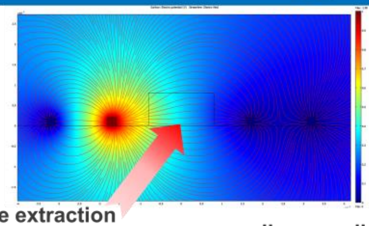
- 8 magnetic poles – 20 coils «spherical» rotor analysis
- Levitation and rotation control confirmed by analysis and tests
- Joule heating assessment and coupled field strength variations

Structural physics & MEMS modeling



CSEM designed NASA/DLR SOFIA airborne astro-telescope "M2 mechanism": FEM details of Flexure design of mirror tip-tilt suspension system, and moment compensation under load

Sensor electric modeling (LF/RF)

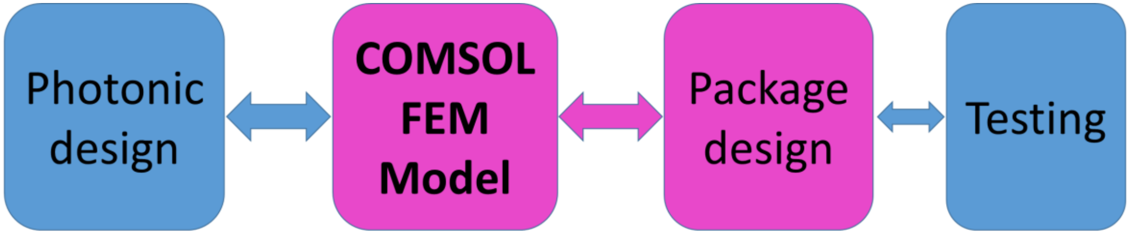


- Capacitance extraction
- Inductance extraction
- S-parameter extraction
- Spice model integration

- coupling possible with thermal and/or mechanical aspects
- 2D & 3D models
- and more …

Mid-IR Laser thermal management considerations

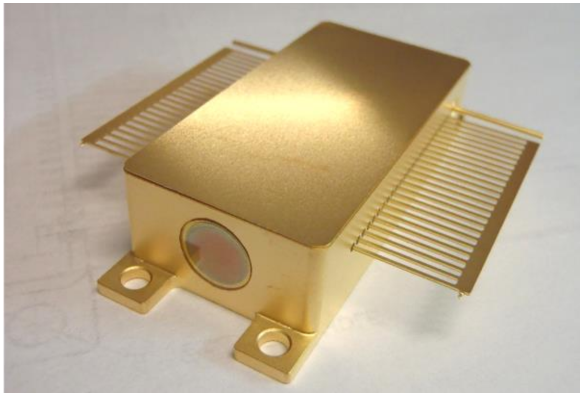
- Mid-IR photonics is growing thanks to advances in Lasers, QC-Lasers, MEMS gratings and fiber optics.
- Temperature is the key to stable and reliable operation of photonic systems
- Thermal management and package design can be handled with multi-physics FEM models



Mid-IR Laser packaging considerations

- Heat-spreading submount to efficiently remove heat
- Thermo-electric cooler (TEC) below heat spreader
- Kovar package to reduce thermo-mechanical stress and enable hermetic sealing.

Mid-IR Laser
with Joule heating
loss of P_{th} ~40(W)



Multi-physics modeling challenges

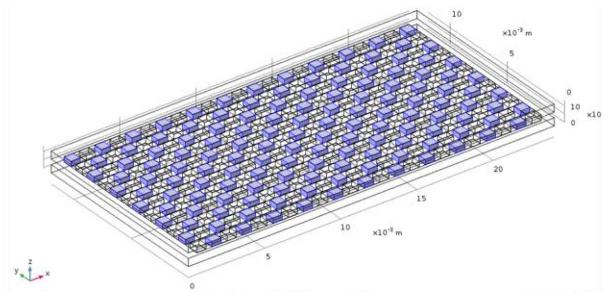
- Conjugated heat transfer (dry air sealed in Kovar package).
- Convective and Radiative effects from external package.
- Multi-physics coupling also to Thermo-electric cooler (TEC).
- Parametric analysis to find optimum laser peak temperature.
- Optimal solver investigation (iterative segregated approach was selected).
  - Extract relevant information with large sweep parameter set
  - Parametric Sweep simulations with both static/transient studies

Selected simulation approach

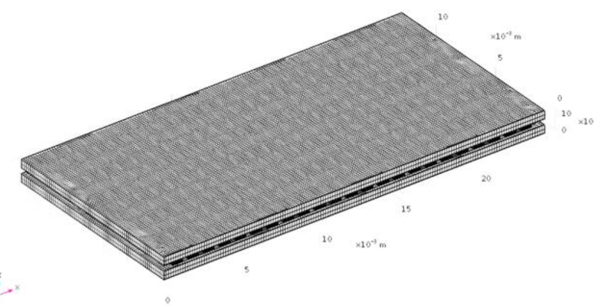
1. Improve TEC model from Comsol Application Library
    - Adding more mesh control (mapped meshing)
    - Adding realistic Thermo-electric pellets measured material parameters
        - Provided by RMT Ltd
        - http://www.rmtltd.ru/
2. Embed model in a full-package enclosure
    - Model air inside the sealed package in quasi-static approach
        - Static simulation is consistent with quasi-static approach
        - Transient simulation is compatible to quasi-static approach for a short time and provides a worst-case almost adiabatic scenario (fluid convecting away from heat source)
    - Added radiation and convection boundary condtions on outer «skin» of the full package model

Thermo-Electric Cooler (TEC) model implementation

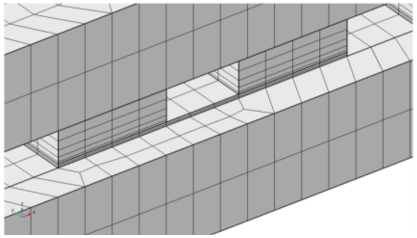
- Use of Comsol Application available in the Application Library
- Improved Mesh approach to cope for large model with 12x24 pellets
- TEC model calibrated with supplier material data (Seeback, k, other…)
- Calibrated TEC model comparison with lumped-model simulator.
  - Heat flux accurate to >99% compared to results from lumped model software developed by TEC supplier



TEC: Δtmax ~71(K), Qmax ~ 56(W)



Zoom on pellets

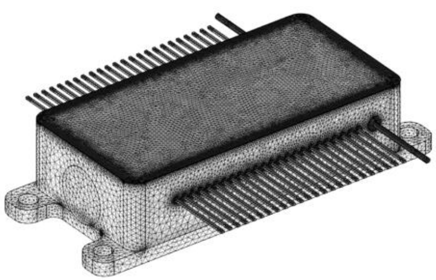


- 120K Elements
- Avg. Element Quality is 0.99 (Skew.)

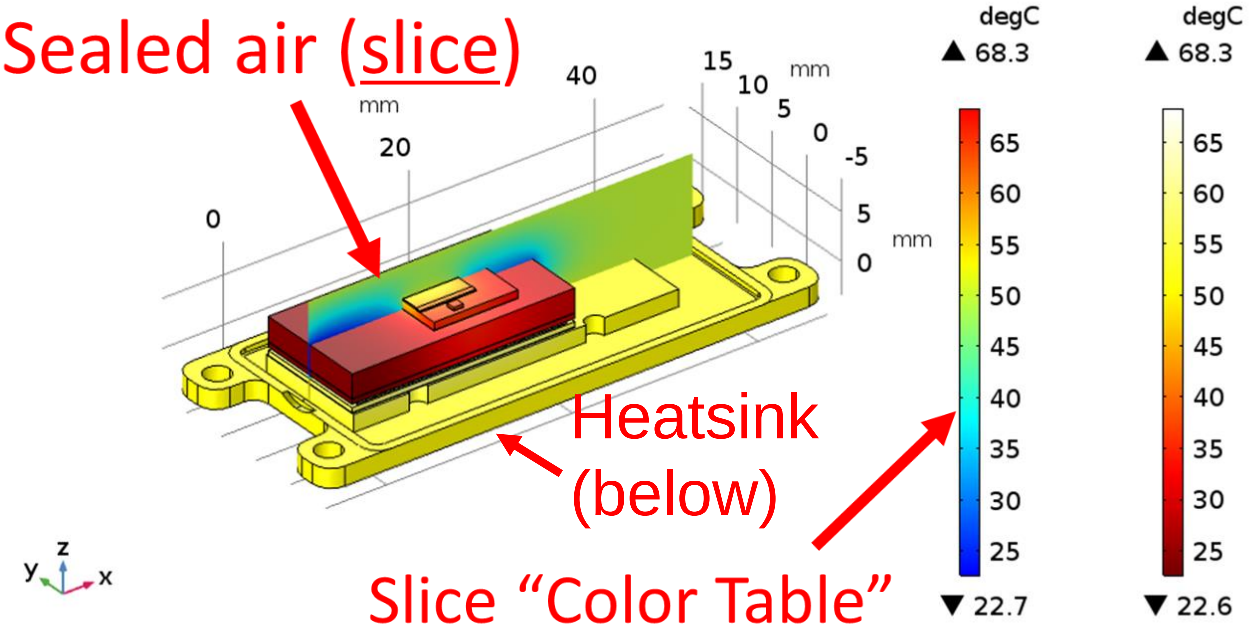
Full Package simulations model implementation

- Large model (high resolution)
- 9 independent parmater set
- 112h solution time

- Ambient of 50°C
- Heatsink @ 22°C

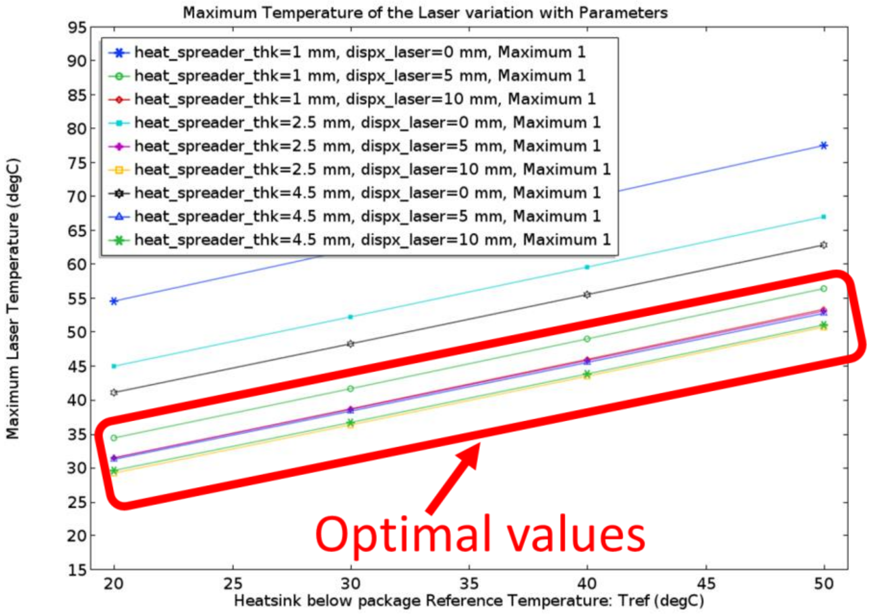


2450K Elements

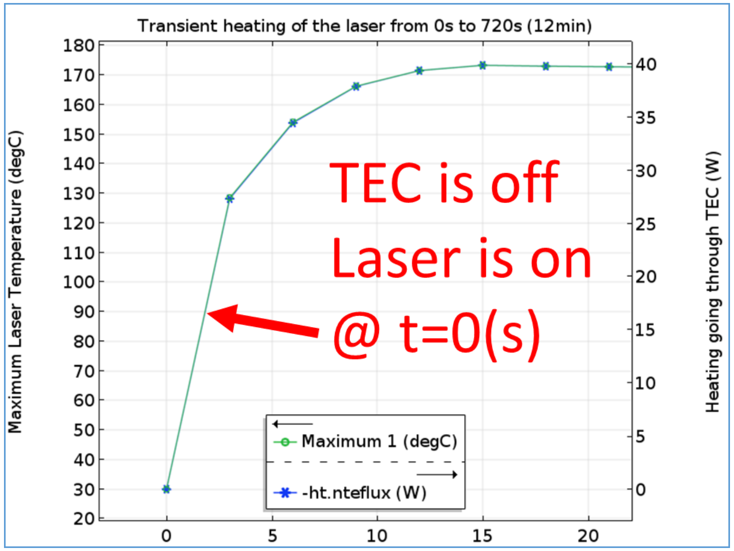


Full Package simulations qualitative results

- Optimal set of submount parameter to minimize the laser peak temperature.
- Optimal laser mount position was found to minimize laser peak temperature.
- Impact of reference heatsink and ambient temperature has been assessed.
- Transient simulation to check the full package thermal time-constant(s).



- **Example of transient results**



Full Package simulations benefits

- Parametric analysis for optimal package components design choice.
  - Skipping trial-and-error effort.
  - Avoiding purchase, assembly and testing costs
- Full-package model provides insight on ambient & heatsink temperatures
  - Impact on the laser max. operating temperature
- Insight on TEC model choice and its detailed behavior
- Transient simulation provides insight on pulsed (LF)
  & short-time operation mode

Conclusions

- **Multi-physics simulation for Packaged Mid-IR Laser results**
  - Laser mounting position on submount is critical along optical axis to achieve minimum laser peak temperature, a position near the middle is optimal (not exactly in the middle).
  - Heat spreader thickness has an impact on laser peak temperature.
    - Thickness of 2.5-4.5(mm) is optimal from thermal stanpoint
  - TEC must be always on if laser is active to avoid damage risk.
- **More information on the above topic available on the Poster**
- **Come and visit us at the CSEM Booth !!**

Thank you for your attention!

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