

Reliability Enhancement of Bio MEMS based Cantilever Array Sensors for Antigen Detection System using Heterogeneous Modular Redundancy

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Introduction: The reliability of the ADS is expressed in terms of the constituent sub systems which are heterogeneous not only in their respective structures and behaviors but also in their forms. The chemical, structural, thermal and mechanical faults are covered to determine the overall reliability of the proposed ADS through modular redundancy.

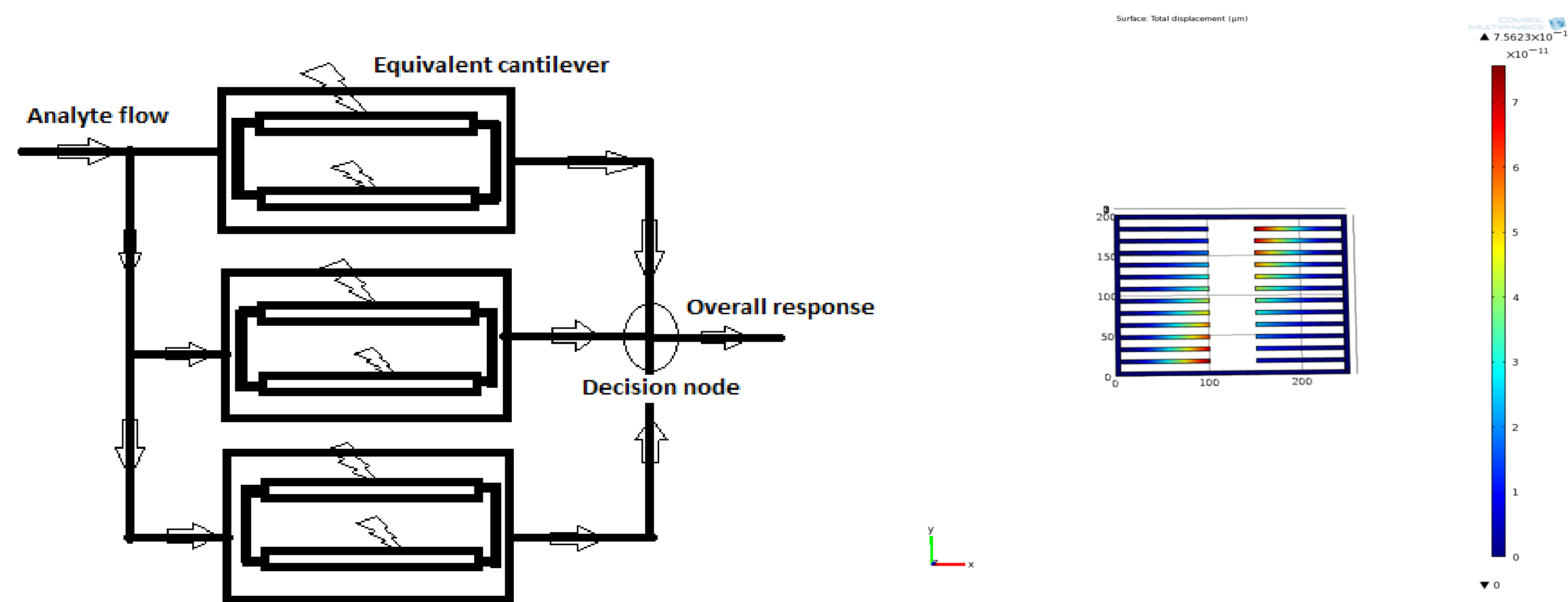


Figure 1. Parallel architecture of the cantilever with holding the mechanical reliability.

Physics and domain equation standing reliability issue: basic modules have been used to describe the models and the domain equations that with stand on reliability includes,

$$R(t) = \Pr\{\xi_s(x) > \xi_L(x), 0 < x \leq t\}$$

$$\Pr\{\xi_s < \xi_L | \xi_L = x\} = \Pr\{\xi_s > x\} = 1 - F_s(x)$$

$$R(t) = R = \Pr\{\xi_s > \xi_L\} = \int_0^{\infty} f_L(x)(1 - F_s(x)) dx$$

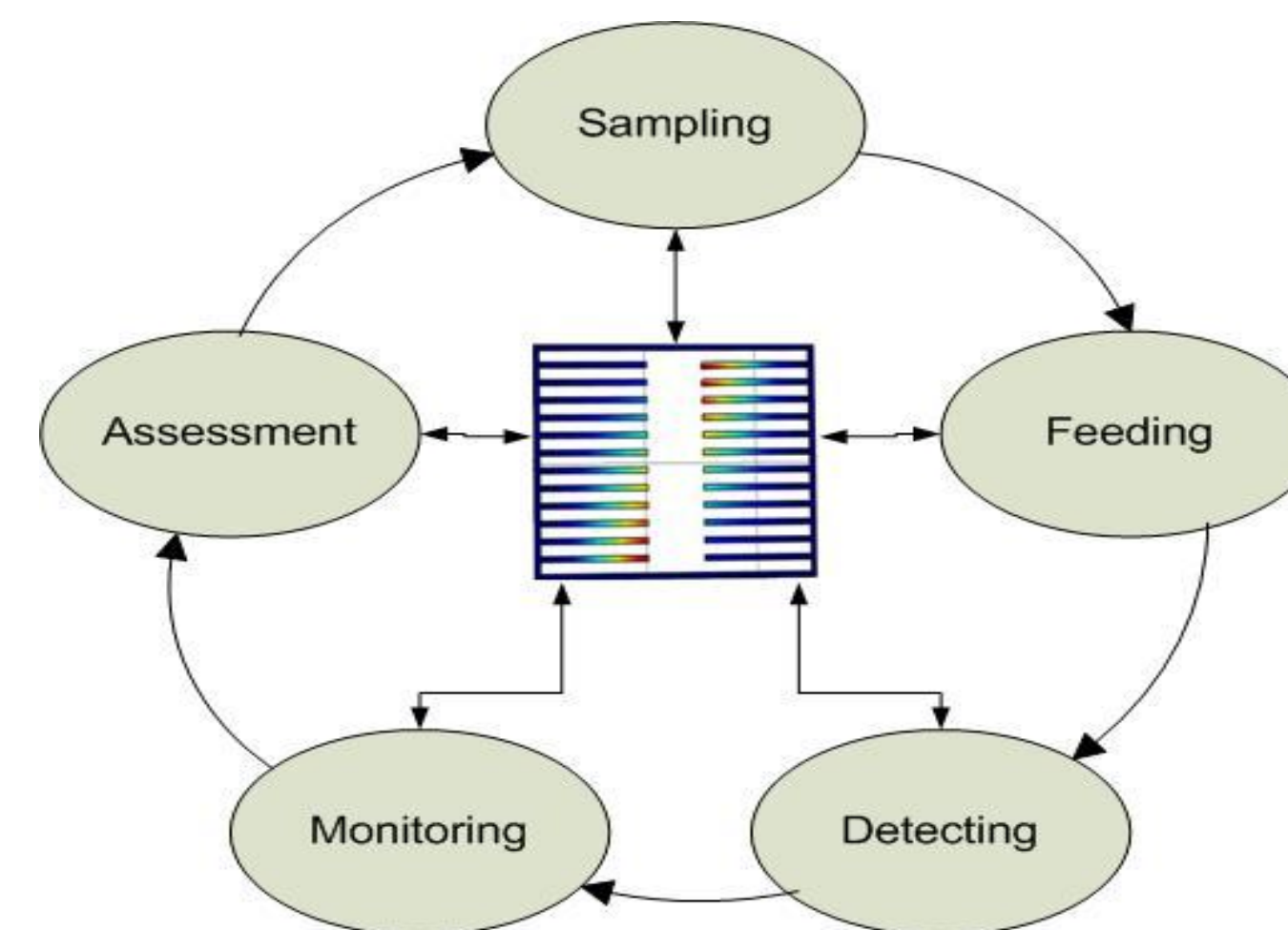


Figure 3. Reliability assessment work flow

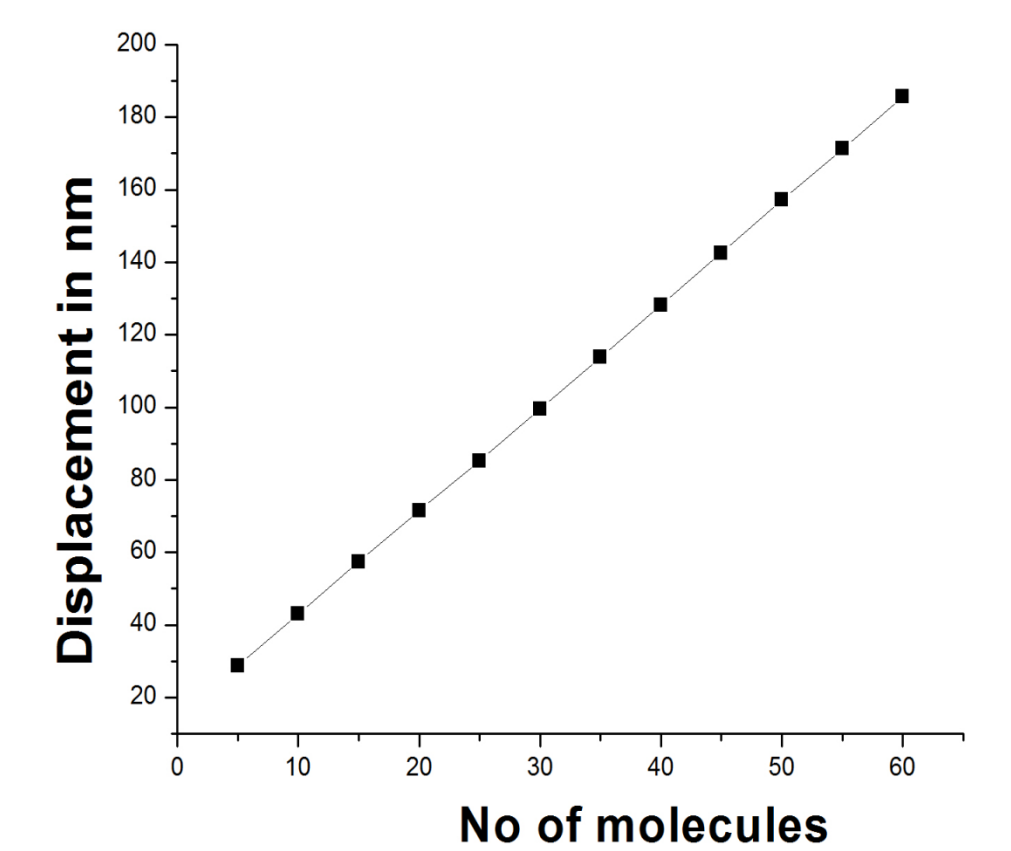


Figure 4. Displacement of the cantilever array with respect to number of molecules interacted with the surface.

Reliability issues:

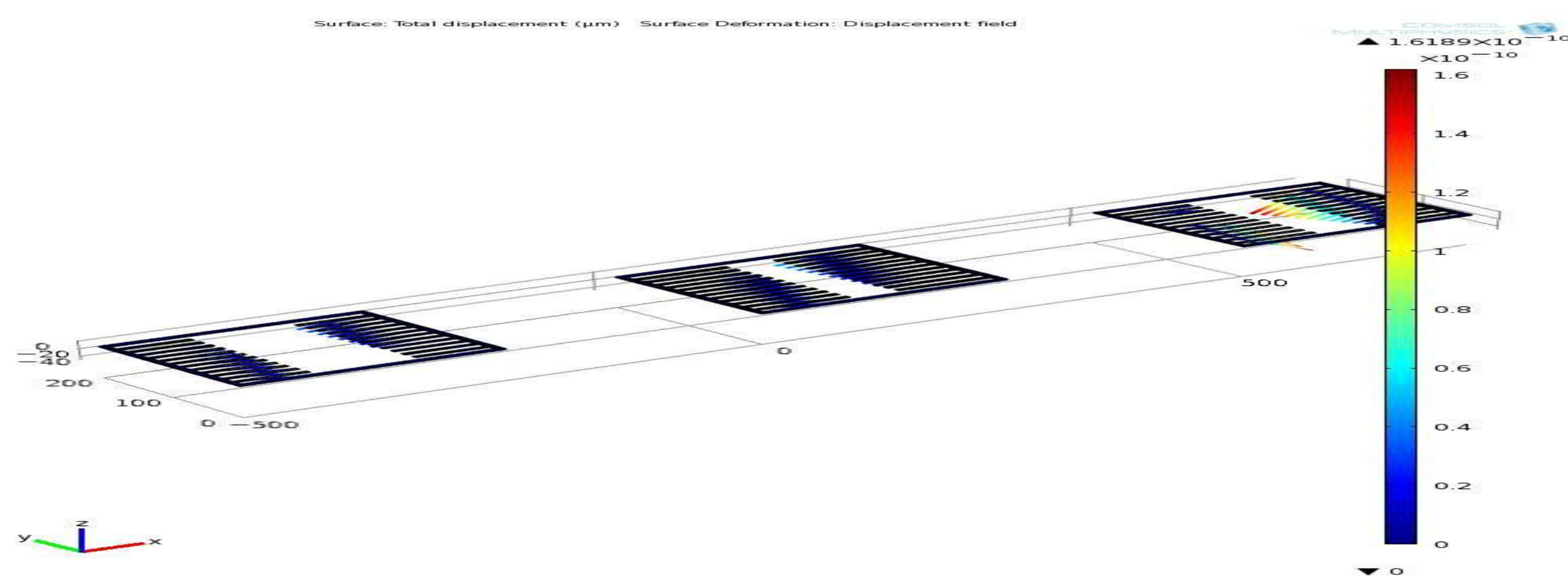
Fault coverage:

1. Displacement caused
2. Mechanical failure
3. Result failure
4. Interaction caused
5. mechanical failure
6. Thermal failure
7. Architectural failure
8. Biological or
9. chemical failure

Failure modes	Reason for failure
Chemical	Material
Thermal	Process
Electrical	Stimuli
Architectural	Structure

To test the reliability of the system, a tripodal heterogeneous modular redundancy model have been used. In which the three cantilever array slots are geometrically different (both in length and breadth), and the final output, interaction bending is given with a probabilistic approach, to find the number of false positives and negatives. This model holds the sensitivity, selectivity, specificity issues.

Inlet blood serum



Output mechanical bending out of Antigen antibody interaction

Figure 2. Reliability enhanced model using a tripodal cantilever array sensor, with cantilever of different thickness and length.

Results:

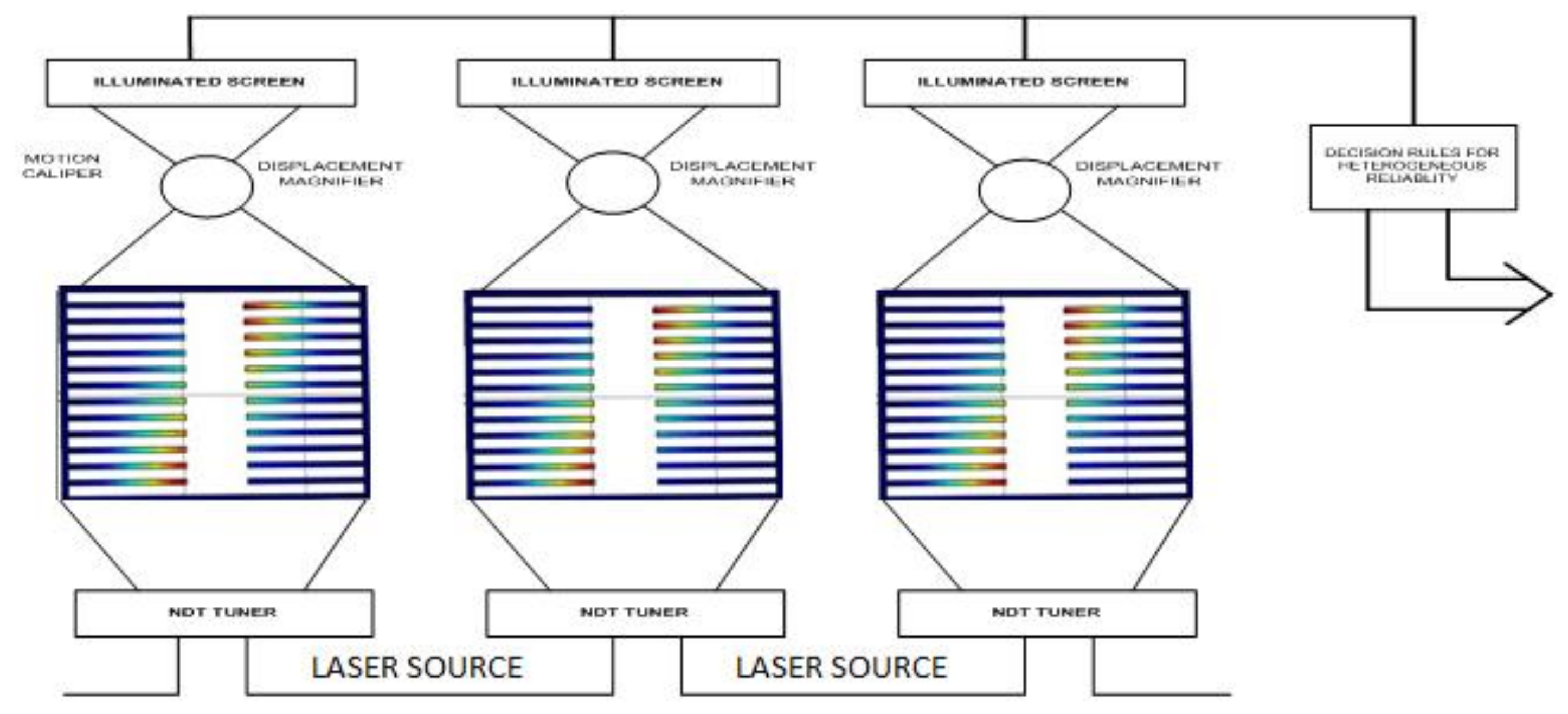


Figure 5. A design model for reliability enhancement using heterogeneous modular redundancy ADS

Conclusions: Thus The reliability of the heterogeneous ADS have been analysed .The possible modes of operation of micro cantilevers are considered and the design diversity principle is applied to enhance the system reliability. The overall reliability status have been analysed to achieve the fault tolerant model, hence forth the sensitivity and specificity of the antibody and the antigen are considered on par with reliability enhancement of individual cantilever. The interaction or binding between antigen and antibody is simulated and the displacement results are achieved using COMSOL Multi Physics package.

References:

1. Logeshkumar. S , Lavanya. L, Anju Gupta, Alagappan. M, "FEM based Estimation of Biological Interaction Using a CantileverArray Sensor", proceedings of Comsol conference 2011.
2. Jeremy A. Walraven, "Future Challenges for MEMS Failure Analysis", Sandia National Laboratories. Albuquerque, NM USA.