

## Modal Analysis of Micro and Nanowires Using Finite Element Softwares

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Received date: 23.12.2018

Accepted date: 15.02.2019

### Abstract

The aim of this work is to represent a quick and truthful modality to obtain frequencies of microwires and nanowires which are widely used in nanosensors, nanocircuit and many more susceptible scientific areas. In this paper, modal analysis of micro and nano sized wires is investigated using COMSOL software. To obtain first ten mode shapes and eigenfrequencies of silicon carbide nanowire, thirty-nine modes is calculated. Results are given in figures captured from the software.

**Keywords:** Modal analysis, microwires, nanowires, SiCNW, COMSOL.

### 1. Introduction

As experimental analyzes of very small structures like carbon nanotubes (CNT), silicon carbide nanotubes (SiCNT), boron nitride nanotubes (BNNT), zinc oxide nanotube (ZnO) and nanowires of homologous structures is very-high costed and take a long time, many methods have been developed to make analysis possible without any experiment. Similarly, atomic simulation and molecular dynamic analysis need too much time to analyze nanotubes in case of buckling and vibration. Continuum mechanics models have been widely used to perform modal, dynamic and stability analysis using mathematical model [1-4]. Computer softwares have also been widely used to perform modal, dynamic and stability analysis in recent years [5-8]. Most of analysis softwares is not able to model structures in micro and nano size. Determining the critical buckling loads and frequencies of nanotubes is very important in case of designing for its particular using areas.

Finite element method (FEM) is a very time-effective method if meshing phase is done properly. This method has been used for a very wide range of analysis. Many different geometries can be modeled using the method such as very complex parts of engineering systems [9-15], beams, plates [16], shells [17, 18], human body parts such as kidney, bone etc. [19-22]. The computer software used to obtain mode shapes and eigenfrequencies is a finite element method based software.



## 2. Modelling Structures

Meshing is the most important part of software analyzes [23]. Inaccurate meshing leads to inaccurate results in modal, dynamic, and stability analyzes. For example, coarse meshing as it can be seen In Fig. 1 (a) would end up with improper results for current model. On the other hand, too fine meshing (Fig. 1 (c)) would end up with accurate and close results to experiments however analyzes would take very long time due to very much calculating vertexes in body.

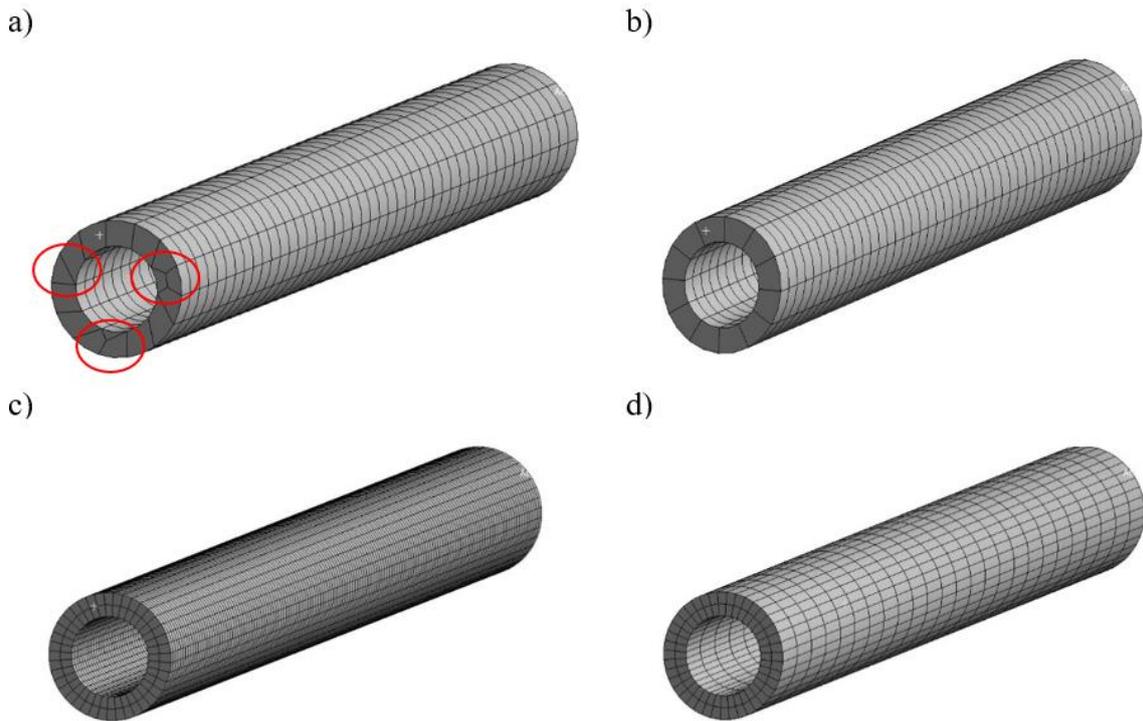
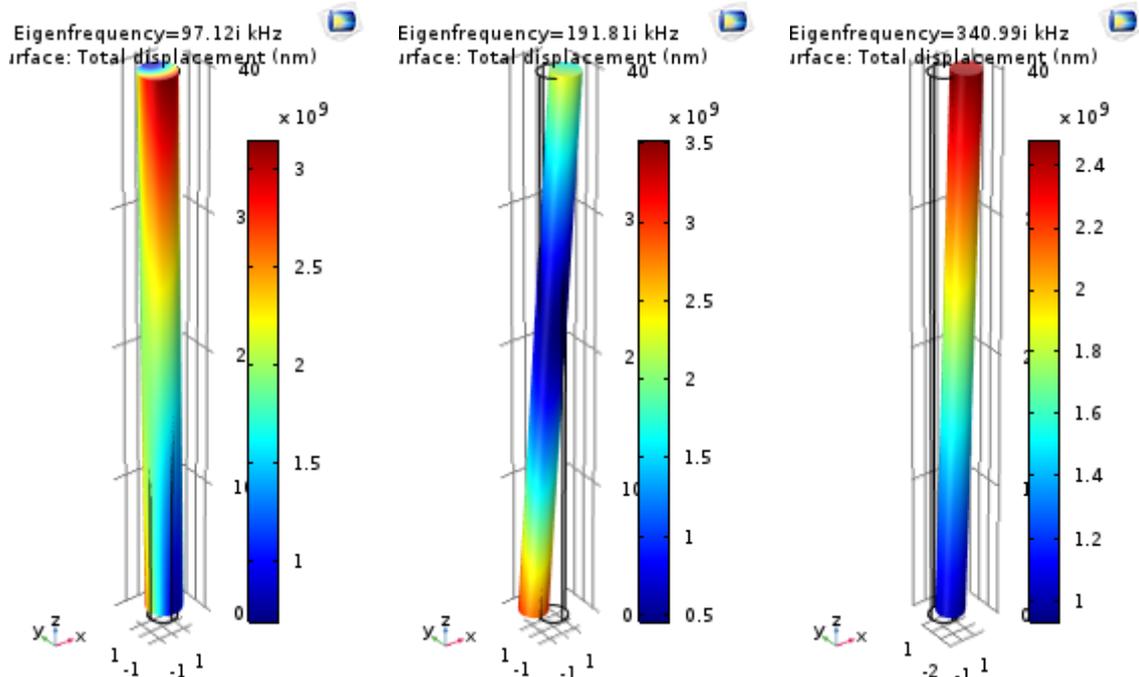


Fig. 1. Meshing nanostructures

Ideal meshing steps of a modeled nanotube is demonstrated in Fig. 1. respectively. In first step, skewed and irregular links between vertexes is observed and demonstrated in red circles (Fig. 1(a)). After fixing this issue (Fig. 1. (b)) it is observed that none of vertex were placed throughout the thickness of nanotube, this issue would lead to inaccurate results due to none of calculation throughout the thickness of nanotube. To overcome this issue, the spacing between vertexes is reduced (Fig. 1 (c)). As it can be seen in Fig. 1 (c). As it is stated before, too fine meshing would take very long time of analyzes due to very much calculating vertexes in body. Spacing between vertexes is extended for the body while reduced spacing is preserved along the thickness of nanostructure (Fig. 1 (d)).

### 3. Modal Analysis of SiCNW

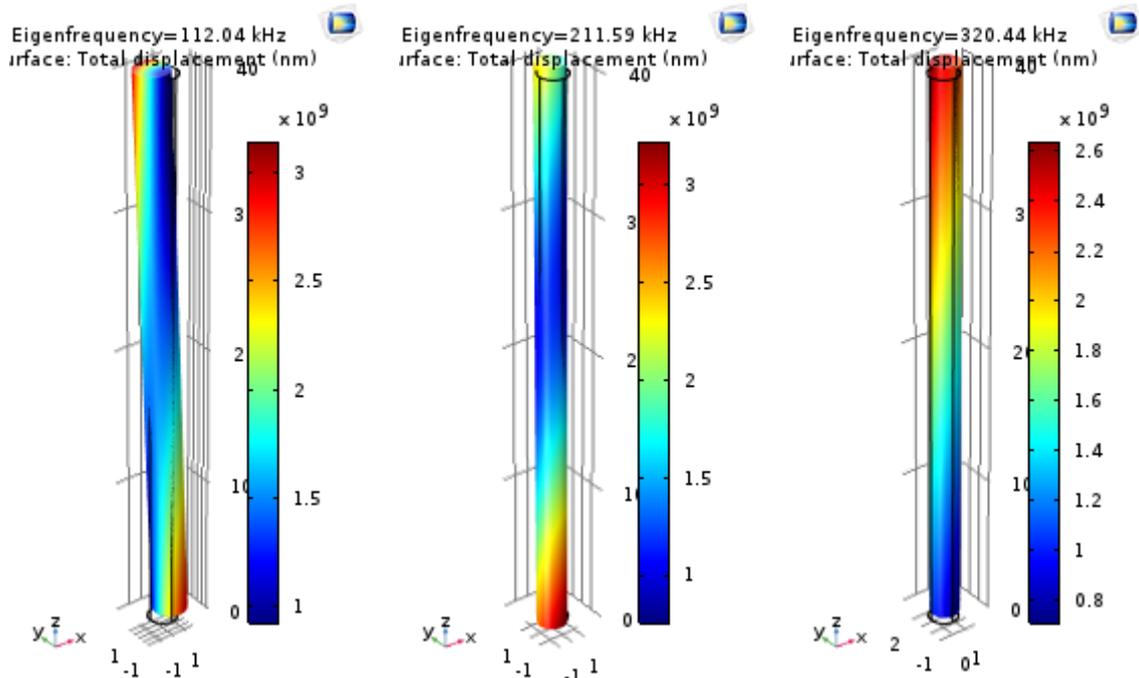
COMSOL Multiphysics [24] is used to model and perform modal analysis on selected silicon carbide nanowire (SiCNW). Subsequent to meshing, needed material properties (Young's modulus 0.62 TPa and Poisson ratio 0.37) and geometrical properties is defined [25, 26]. Eventually, intended boundary conditions is defined (simply support in this case).



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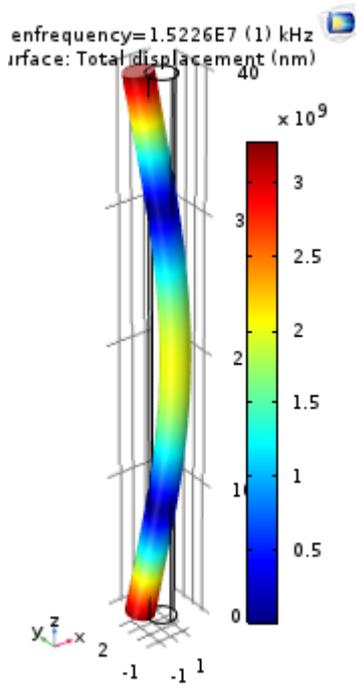
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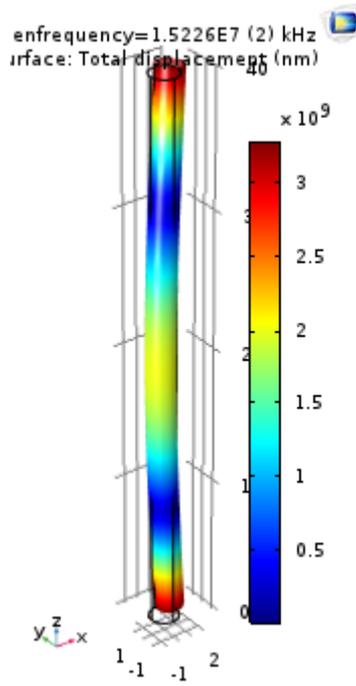
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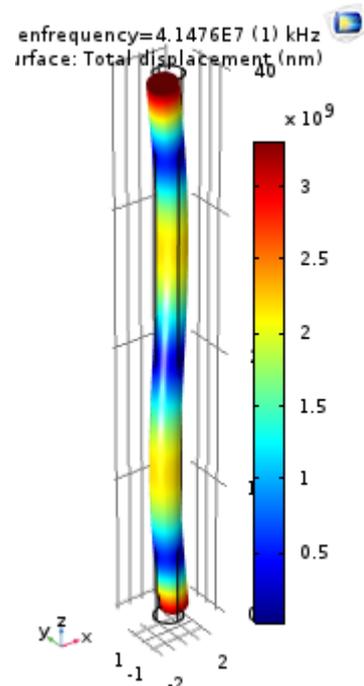
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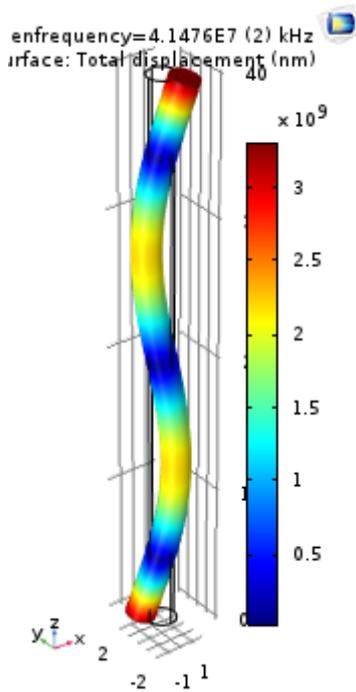
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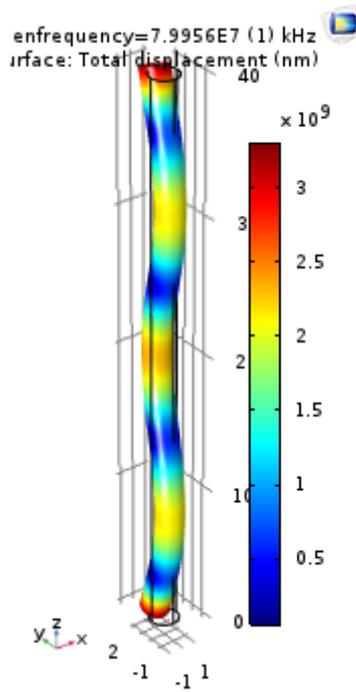
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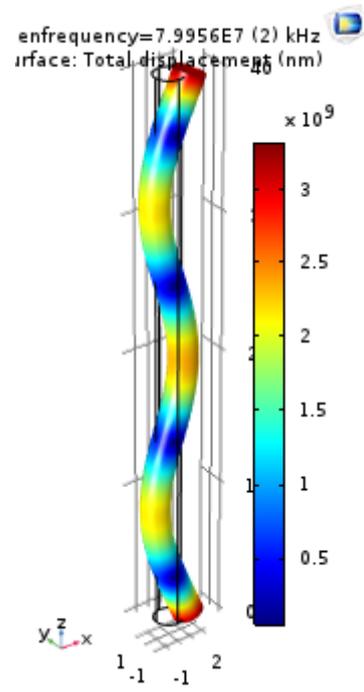
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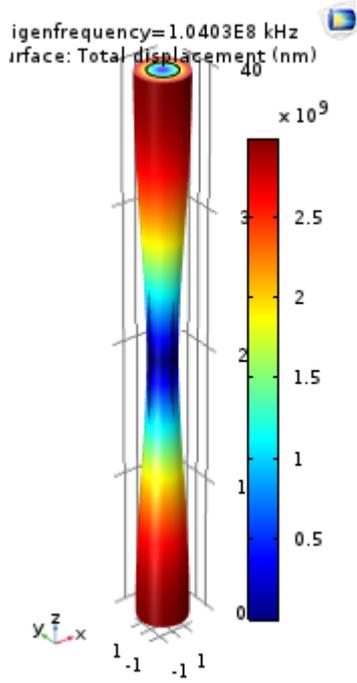
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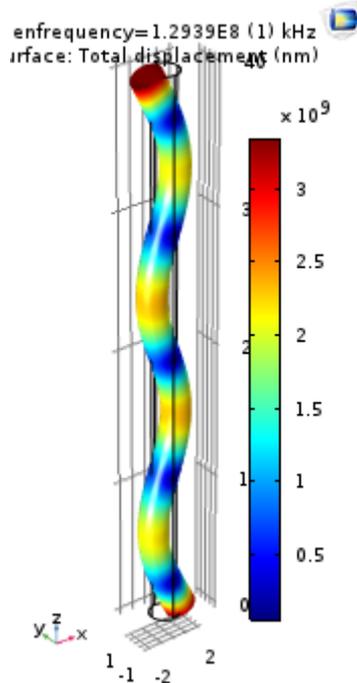
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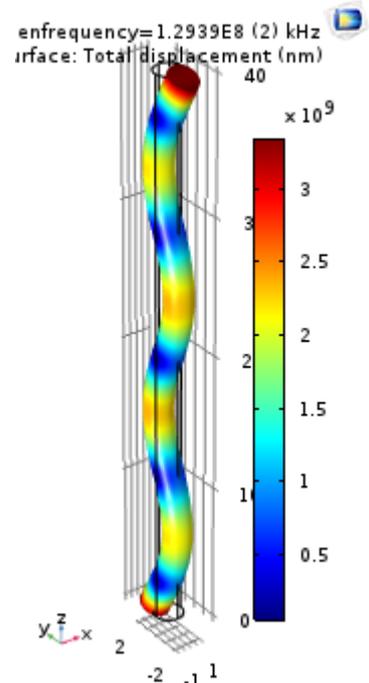
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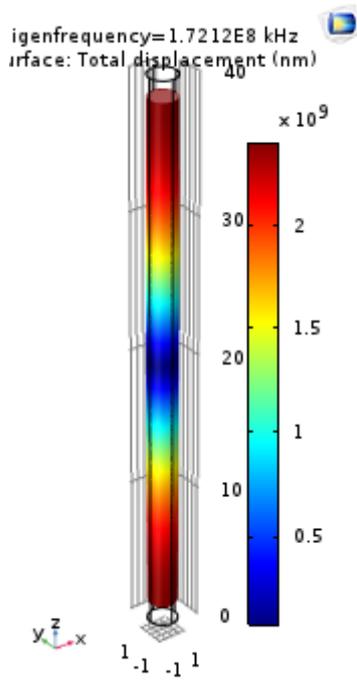
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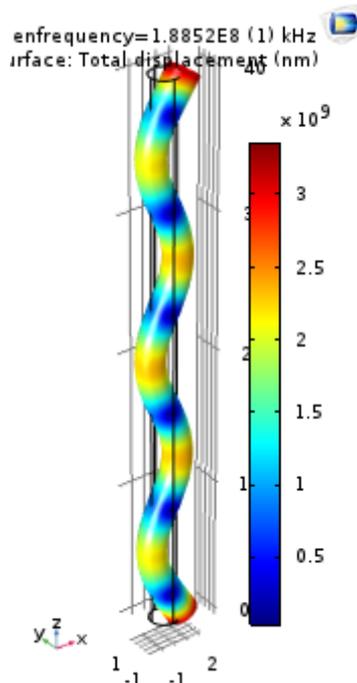
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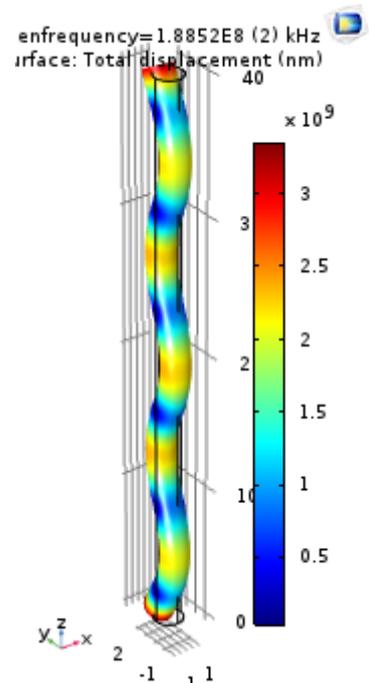
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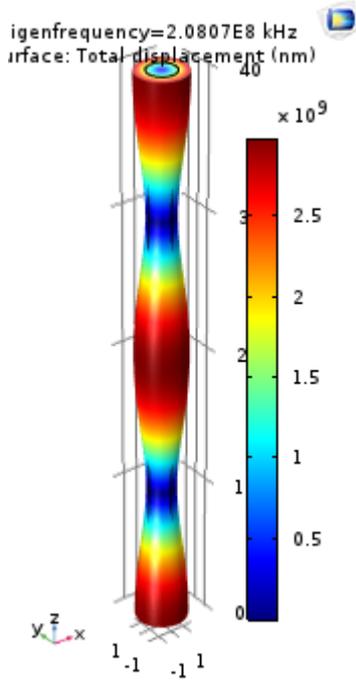
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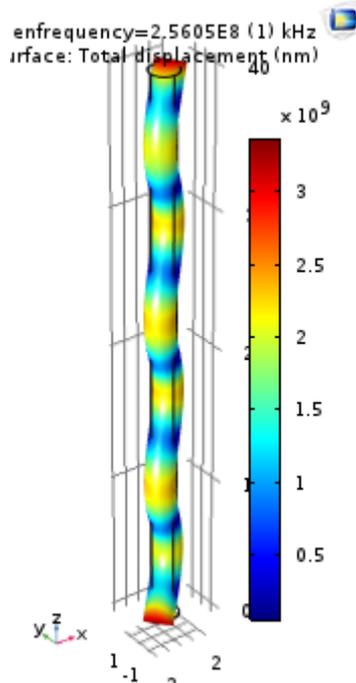
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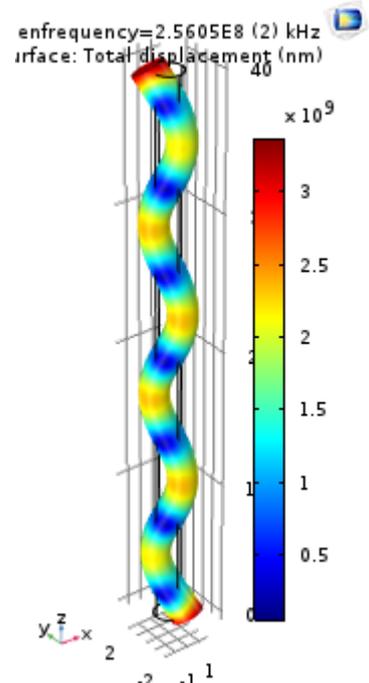
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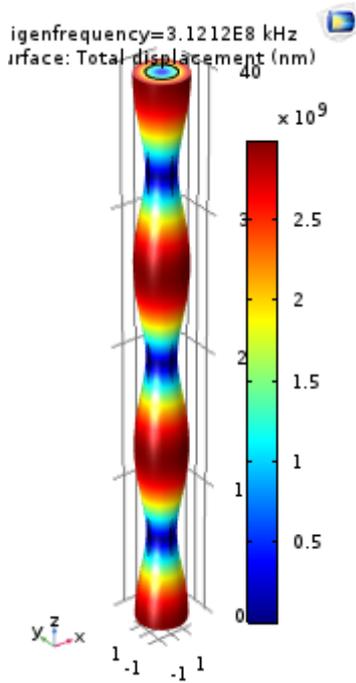
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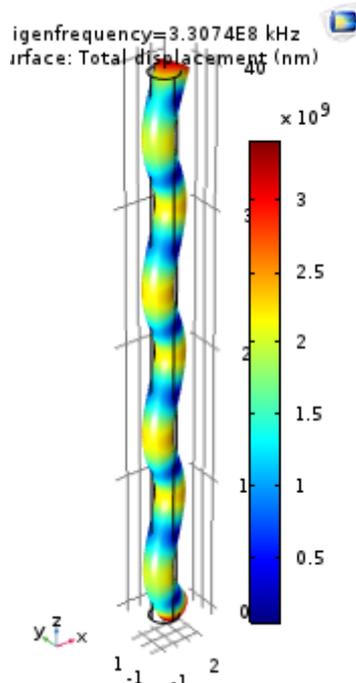
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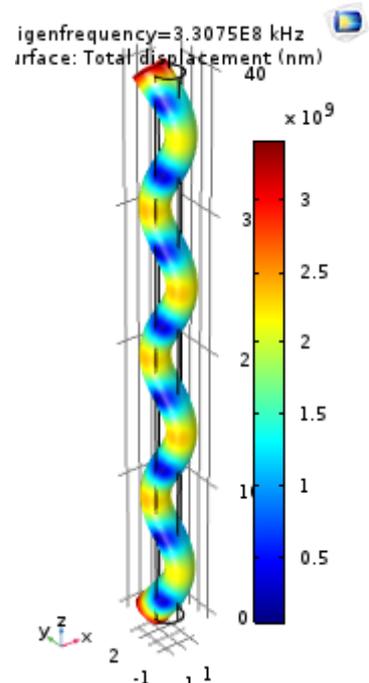
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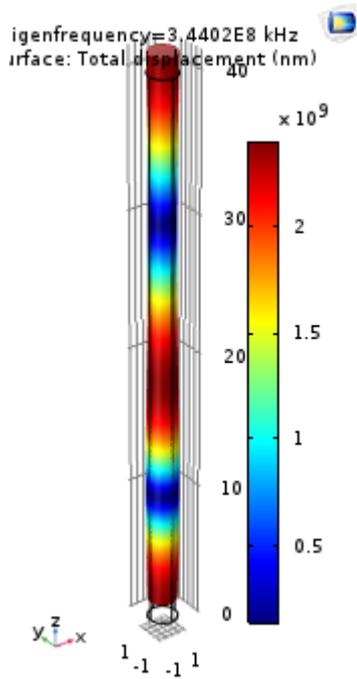
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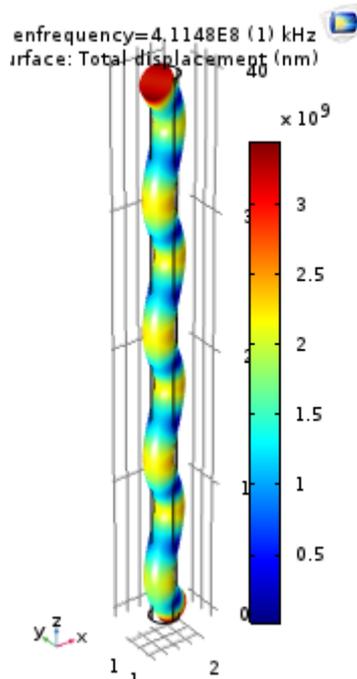
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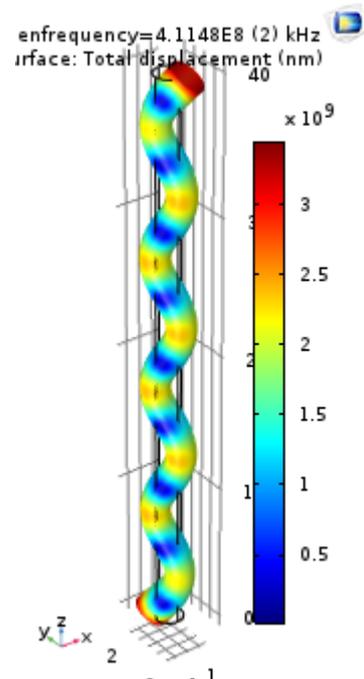
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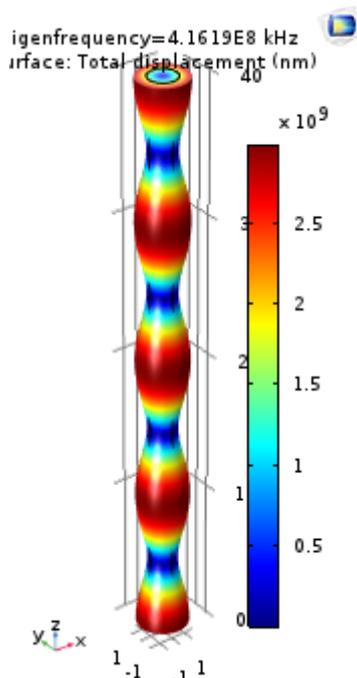
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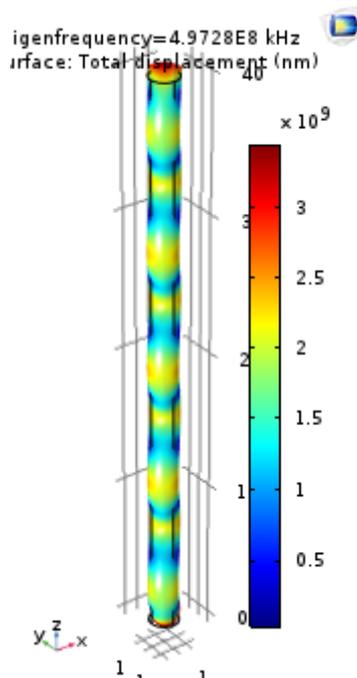
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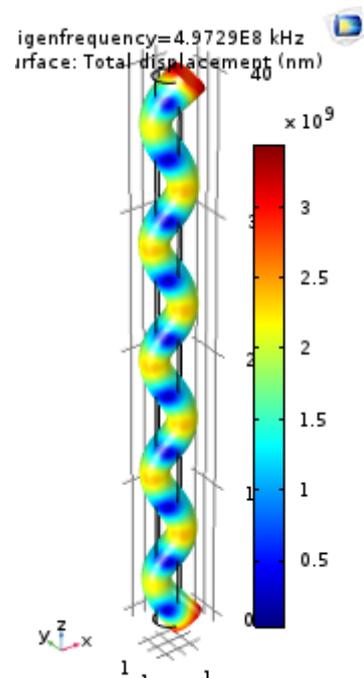
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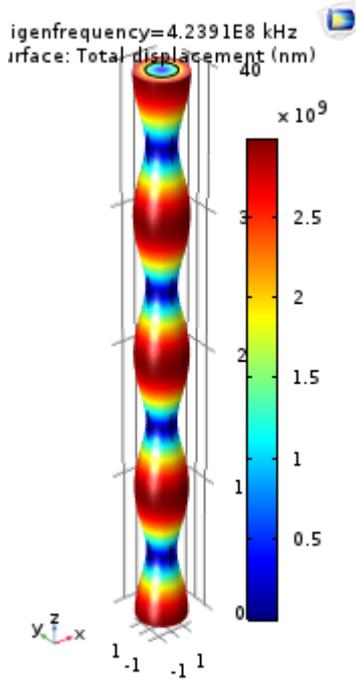
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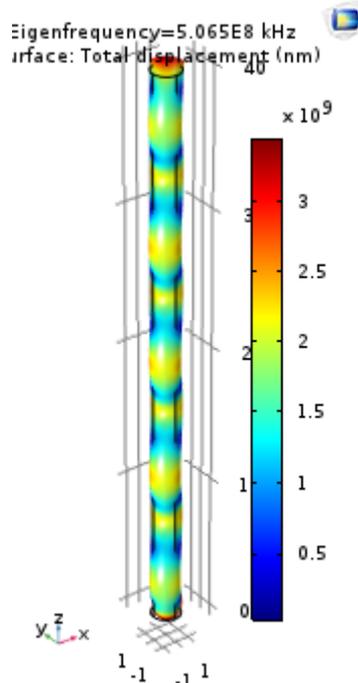
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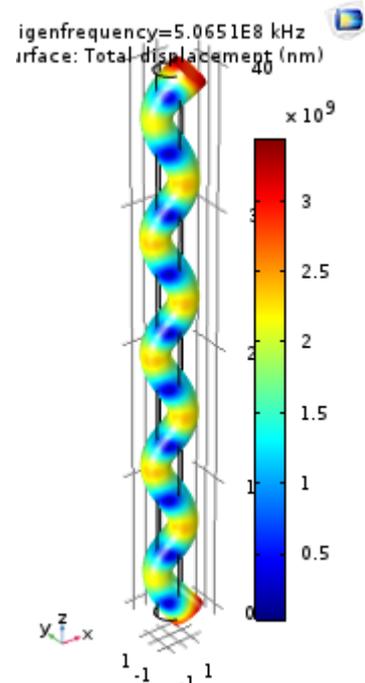
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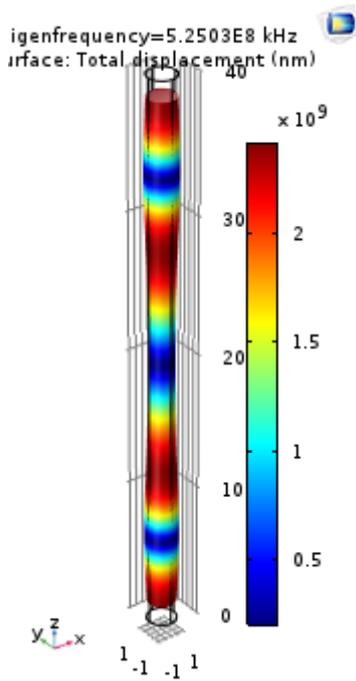
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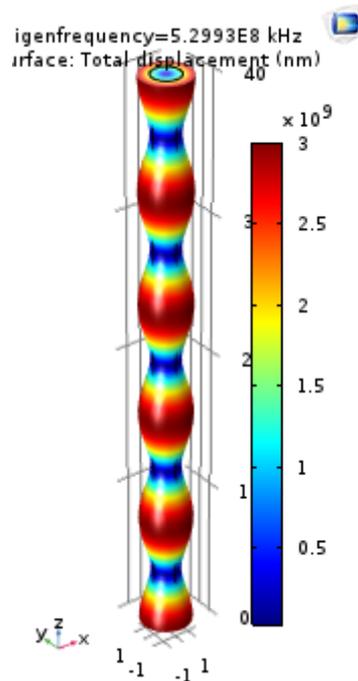
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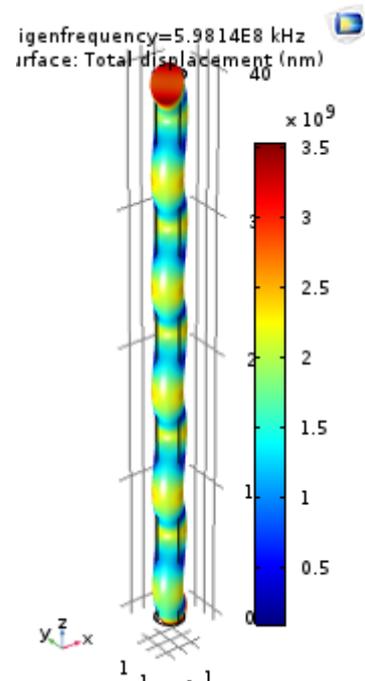
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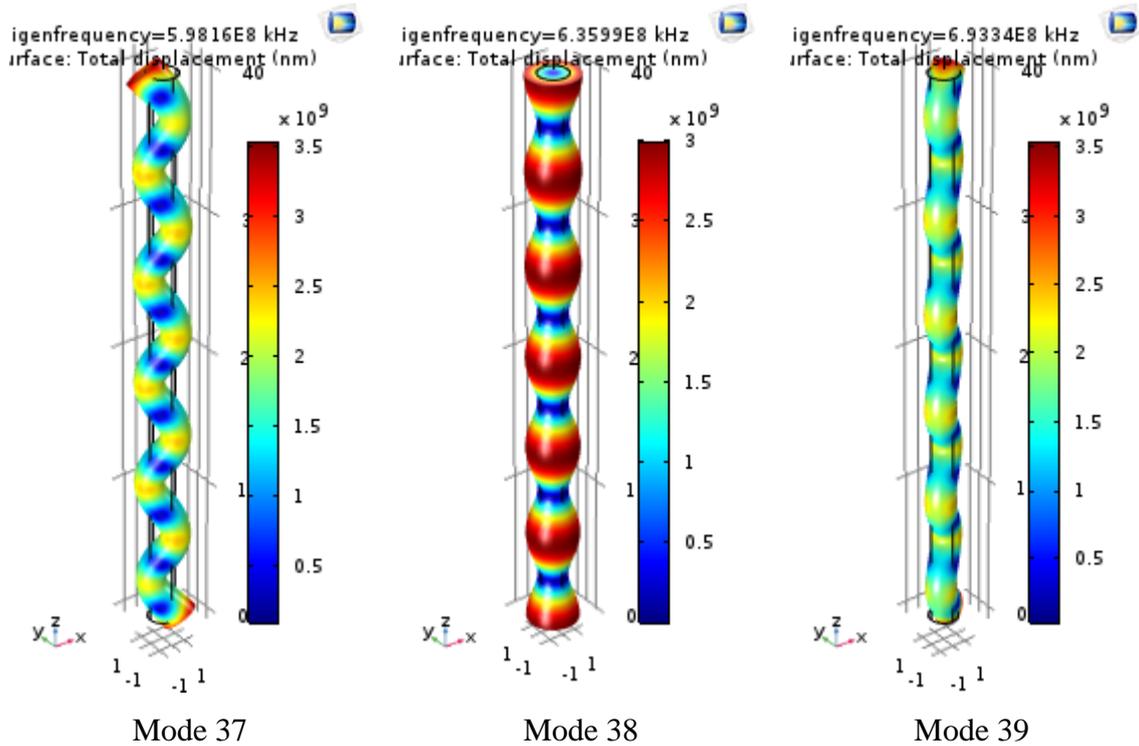
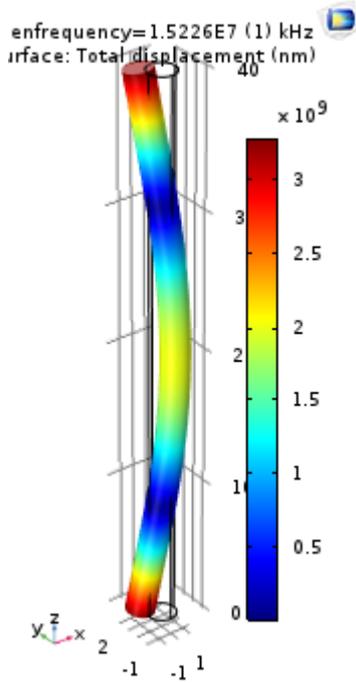


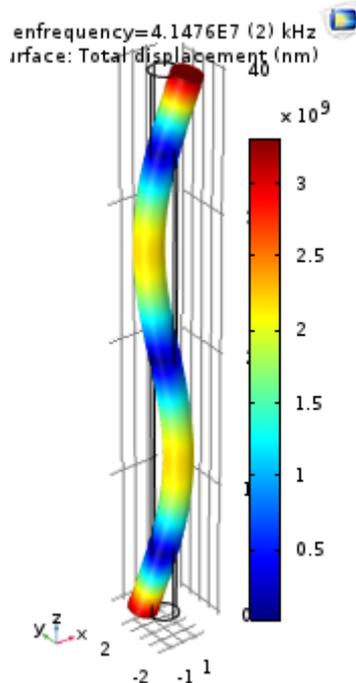
Fig. 2. First thirty-nine modes of SiCNW

The aim of the analysis is to obtain first ten eigenfrequency values and mode shapes of silicon carbide nanowire (SiCNW). First thirty-nine modes of SiCNW is calculated and results are demonstrated in Fig. 2. The cause to calculating thirty-nine modes is to obtain the proper first ten modal analysis results. As it can be clearly seen from Fig. 2, mode number calculated by the software include symmetrical modes and undesirable distensions modes. To overcome this issue, first ten mode numbers need to be selected carefully from thirty-nine mode shapes.

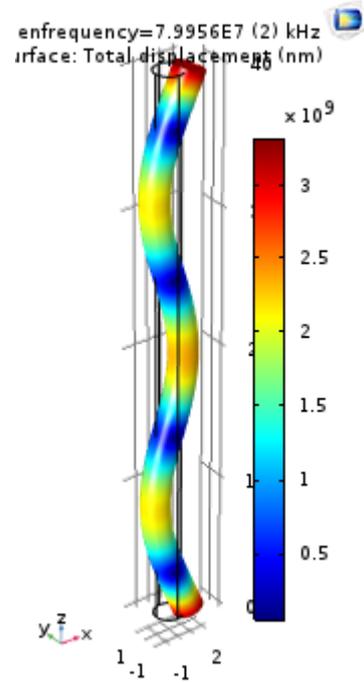
Sifting mode shapes can be easily done by visual choosing in current software. Familiar mode shapes can be easily differed from others while symmetric shapes need some more attention. In Fig. 3, selected and intended analyzes results is demonstrated with related eigenfrequencies.



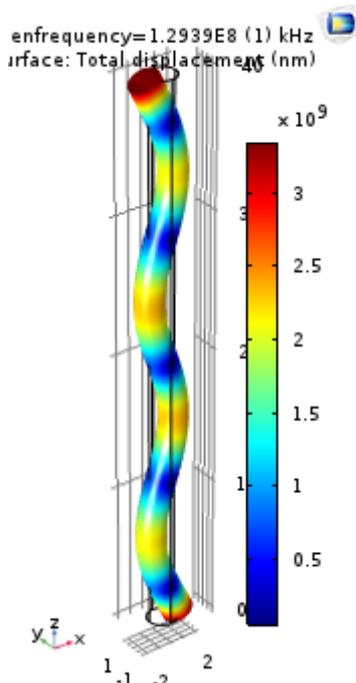
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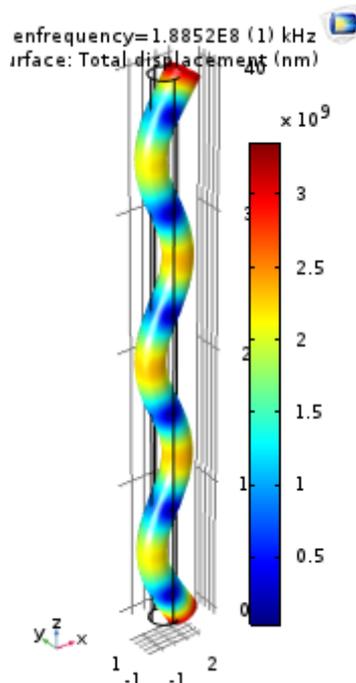
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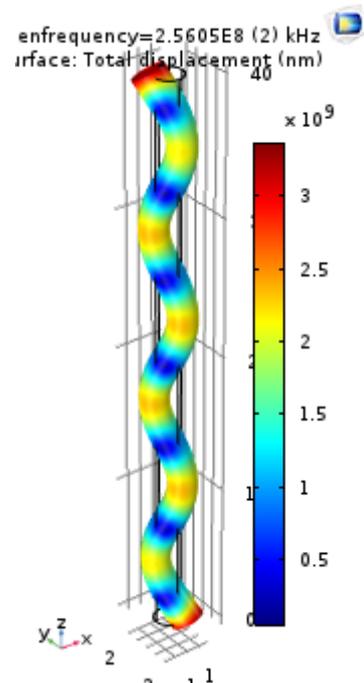
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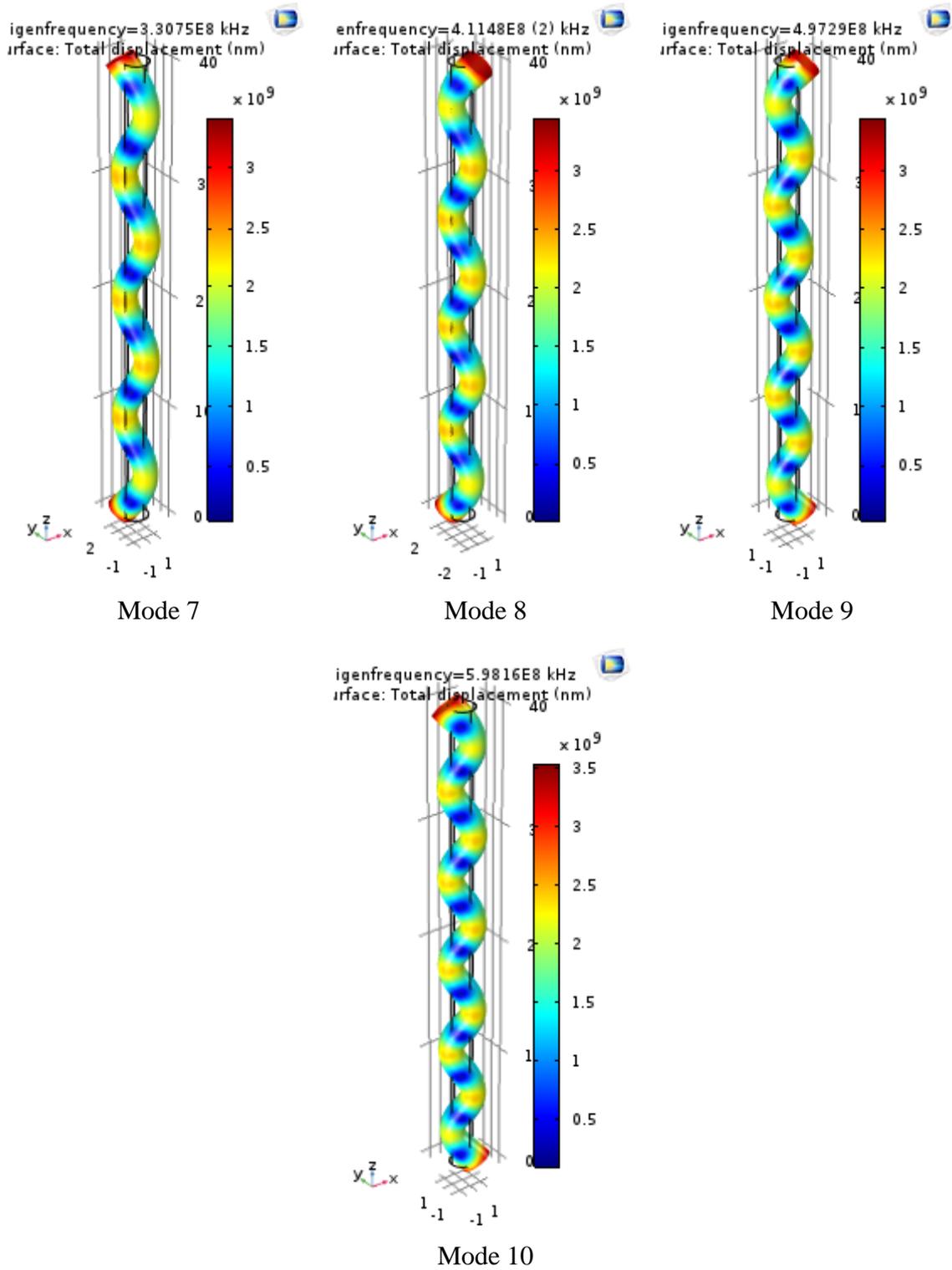


Fig. 3. Sifted first ten modes of SiCNW

## 5. Conclusions

In present study, the modal analysis of SiCNW is investigated using COMSOL Multiphysics computer software. Also, the right way of meshing and preparing micro and nano sized structures is demonstrated. To obtain intended first ten modes of SiCNW, thirty-nine modes needed to be calculated. After calculating mode shapes, results are sifted and desired first ten mode shapes are illustrated with related eigenfrequency value. This is a paper to give the introduction to finite element analysis softwares in micro and nano sizes. The future works can be comparing these results with size effective theories and see the validation of size effective constants.

## Acknowledgements

The financial support of the scientific research projects unit of Akdeniz University is gratefully acknowledged.

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