DTU Library

Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

Fasil, Muhammed; Mijatovic, Nenad; Holbøll, Joachim; Jensen, Bogi Bech; Almunia, J.; Seoane, A.; Altimira, R.

Publication date:
2015

Document Version
Peer reviewed version

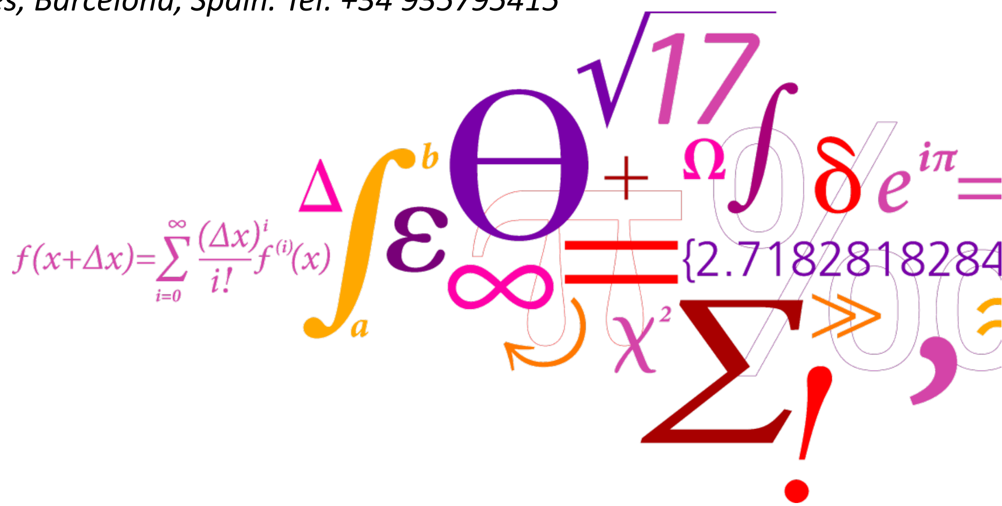
Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

M. Fasil[a], N. Mijatovic[a], J. Holbøll[a], B.B. Jensen[b], J. Almunia[c], A. Seoane[c], and R. Altimira[c]

[a]Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark. Tel: (+45) 45 25 35 00;

[b]Department of Science and Technology, University of the Faroe Islands, Torshavn, FO-100, Faroe Islands. Tel: +298 292560

[c]IMA S.L., Avda. Rafael Casanova 114, 08100 Mollet del Vallés, Barcelona, Spain. Tel: +34 935795415



Presented by

Muhammed Fasil

Ph.D. Student

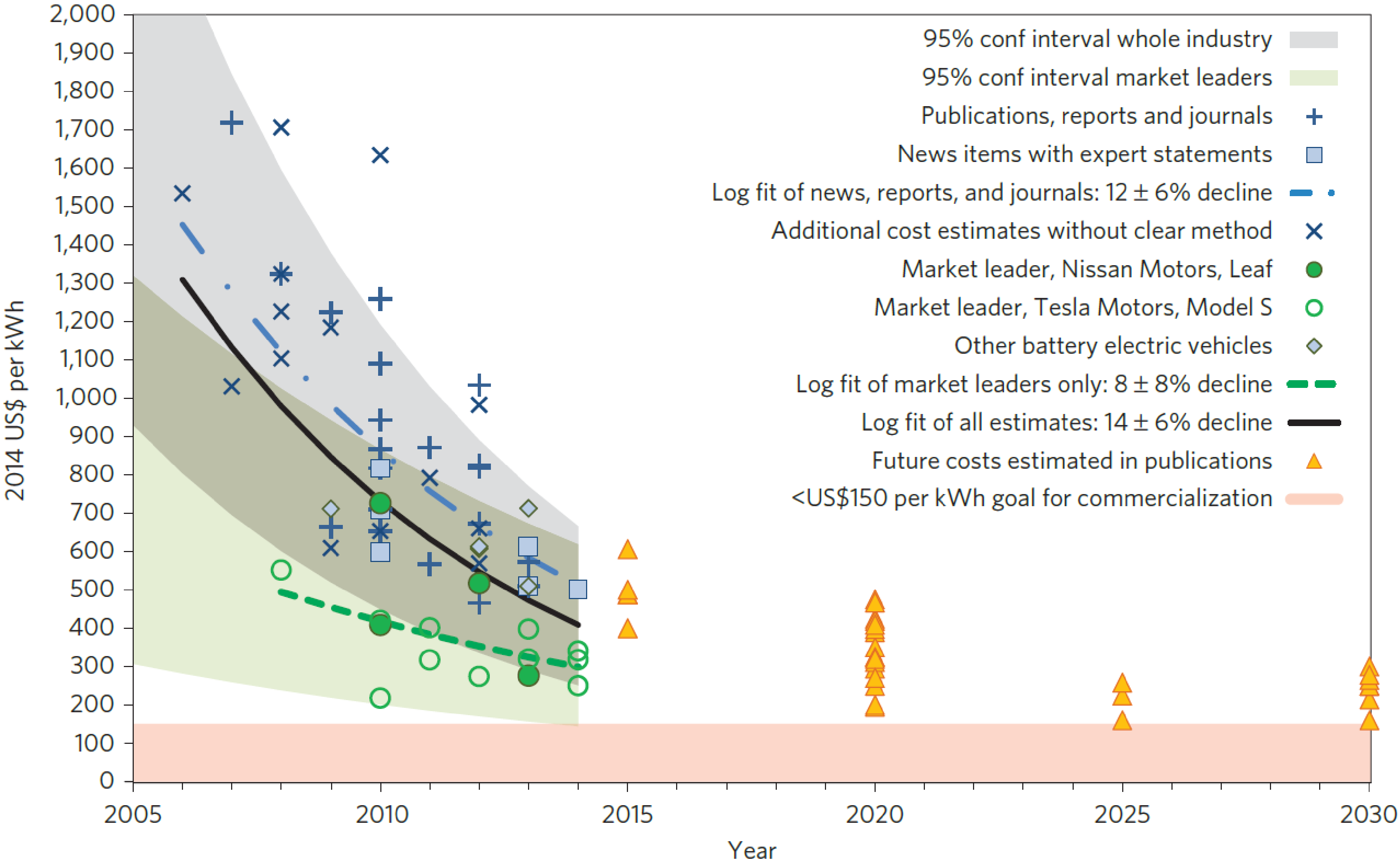
DTU Electrical Engineering

Department of Electrical Engineering

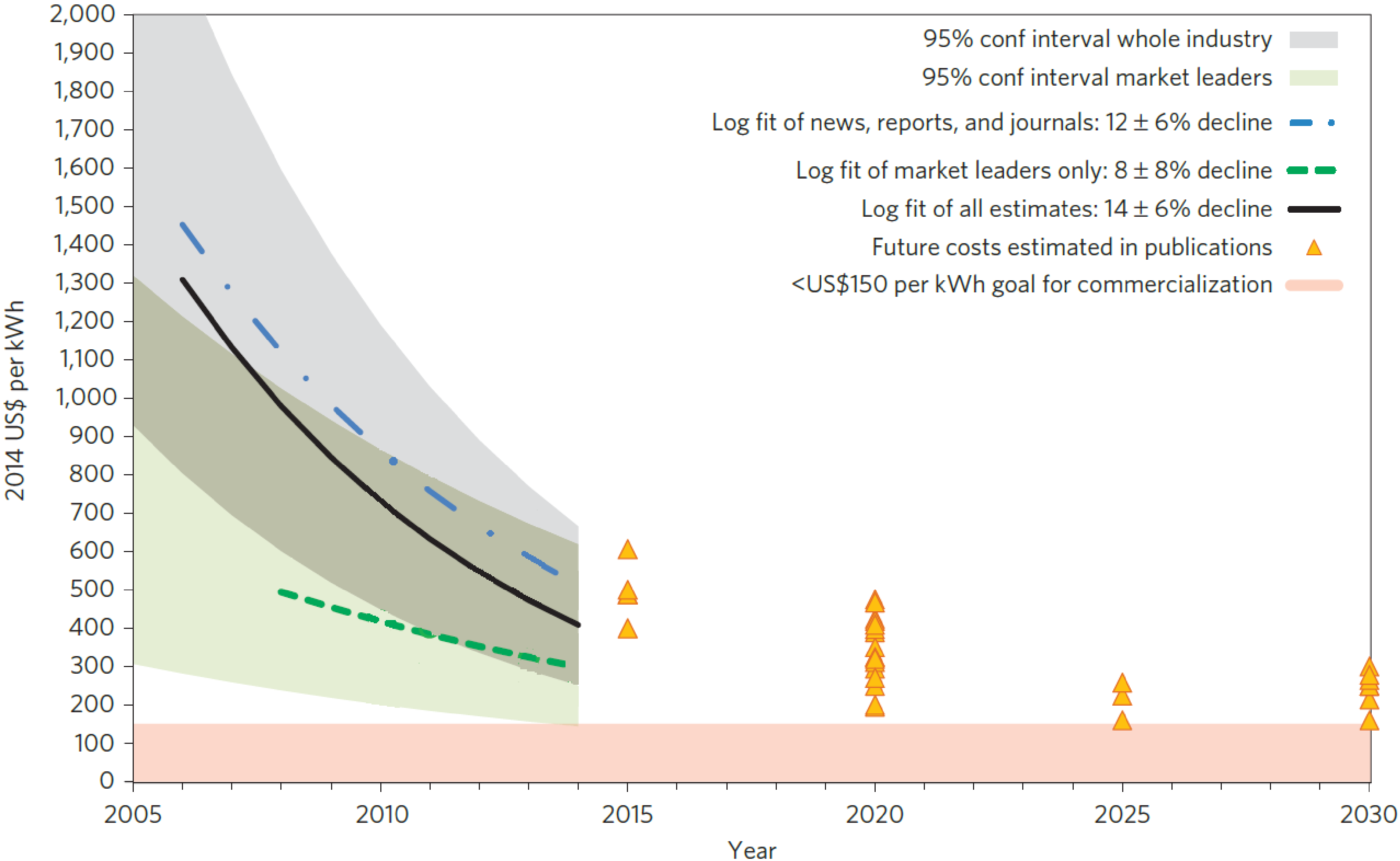
Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations

- At present, performance/price factor compared to IC engine vehicles are holding back the growth of EVs



[1] B. Nykvist and M. Nilsson, "Rapidly falling costs of battery packs for electric vehicles," Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.



[1] B. Nykvist and M. Nilsson, “Rapidly falling costs of battery packs for electric vehicles,” Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.

Background - Importance of improved ferrite magnets to the growth of electric vehicle

DTU

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations
- At present, performance/price factor compared to IC engine vehicle are holding back the growth of EV
- The cost of batteries used in electric vehicles (EVs) has been falling fast and is almost certainly well below the estimates made by many analysts in the past decade[1].
- A low cost powertrain could lead to affordable, efficient and performing EVs in market earlier than expected!
- Introduction of improved energy density ferrite magnet based PM motors is a possible solution to low-cost powertrain

[1] B. Nykvist and M. Nilsson, "Rapidly falling costs of battery packs for electric vehicles," Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.

Outline

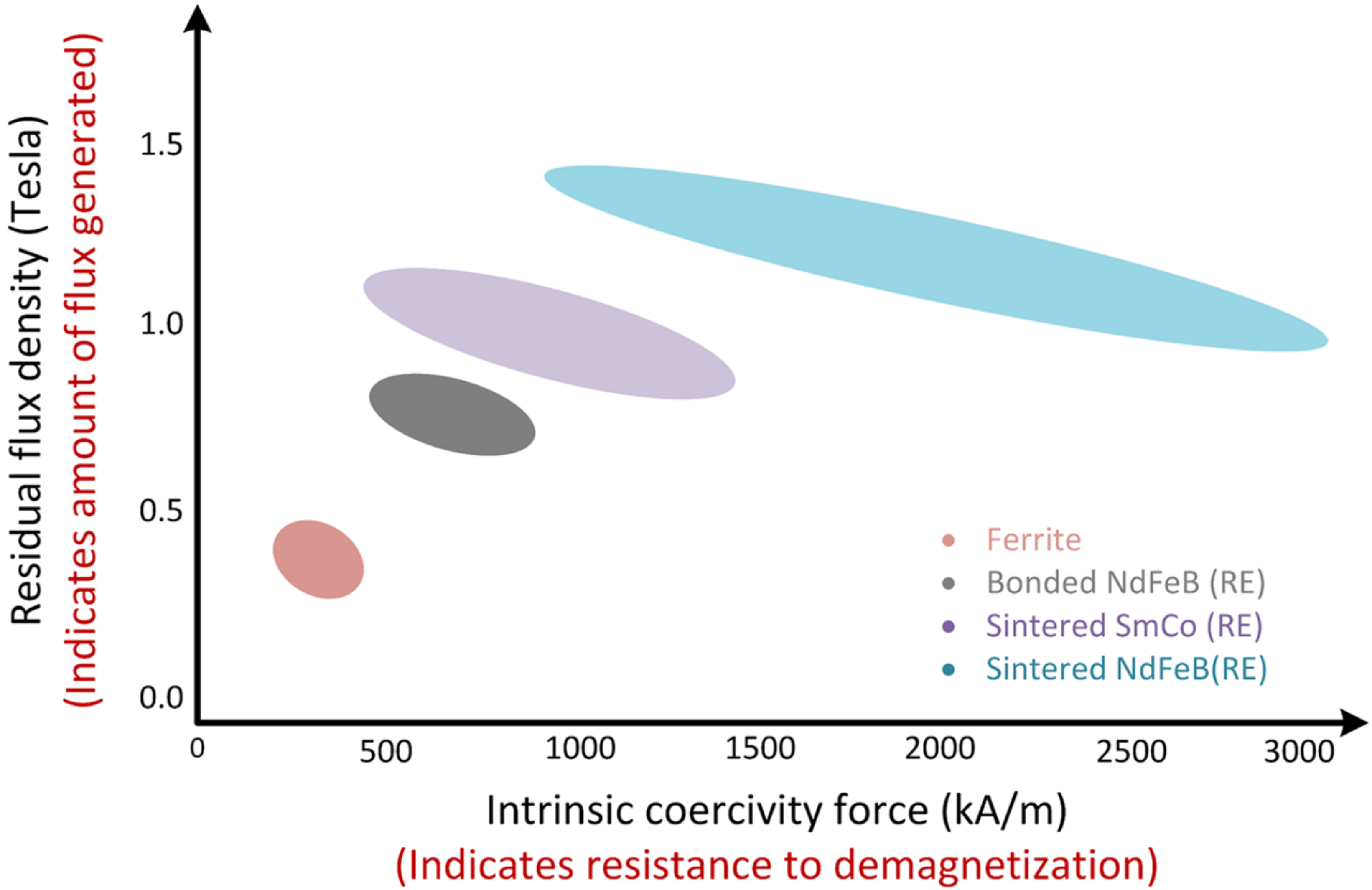
- Background
- Specification of electric motor powertrain for two-wheeler
- Challenges in substituting rare earth magnet with ferrite in electrical machines
- Design details of ferrite magnet motor
- Mechanical assembly of motor
- Fabrication of the motor
- Conclusion

Specification of electric motor powertrain for two-wheeler

Emmo electric scooter
[**Existing motor:** Sintered rare earth permanent magnet motor]

Specification of vehicle drive			
S.N	Name	Unit	Value
1	Maximum vehicle mass including load	kg	130
2	Maximum (Rated) vehicle speed	kmph	30
3	Time to reach rated speed of vehicle	s	15
4	Rated speed of motor	rpm	330
5	Rated power of motor	W	700
6	Rated torque	Nm	20
7	Rated voltage	V	48

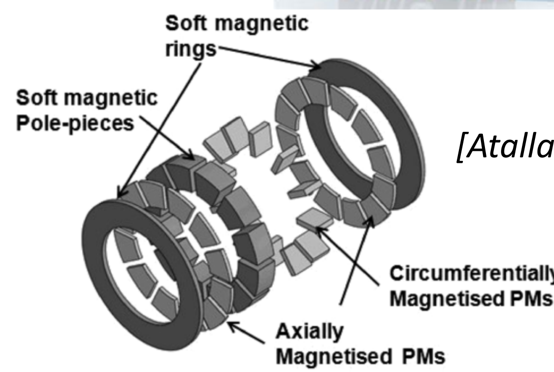
Challenges in substituting rare earth magnet with ferrite in electrical machines



Challenges in substituting rare earth magnet with ferrite in electrical machines

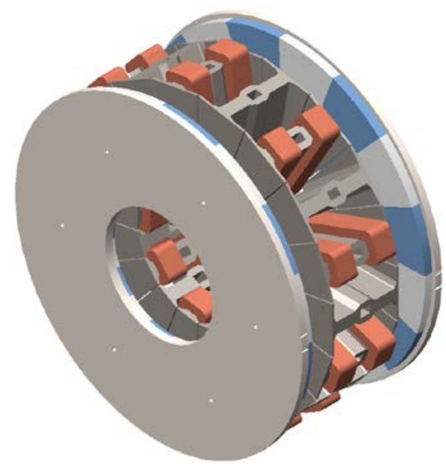
- What others are doing
  - Motor without any magnets
    - Switched reluctance motors
    - Synchronous reluctance motors

  - Motor with magnets
    - New topologies to that allows putting more magnet in an efficient way such as axial flux machines, dual rotor machines



[Atallah2012]

- Nanopyme motor topology and configuration offers
  - Low cost position sensing and simple controller
  - Easy to wound and easy to repair modular concentrated winding
  - Direct drive with no gears offers lesser components and improved reliability



Nanopyme motor topology

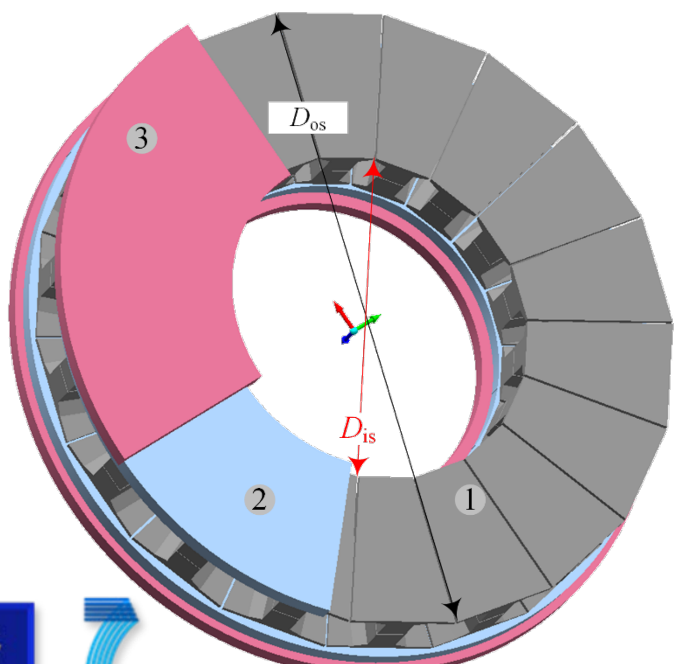
Design details

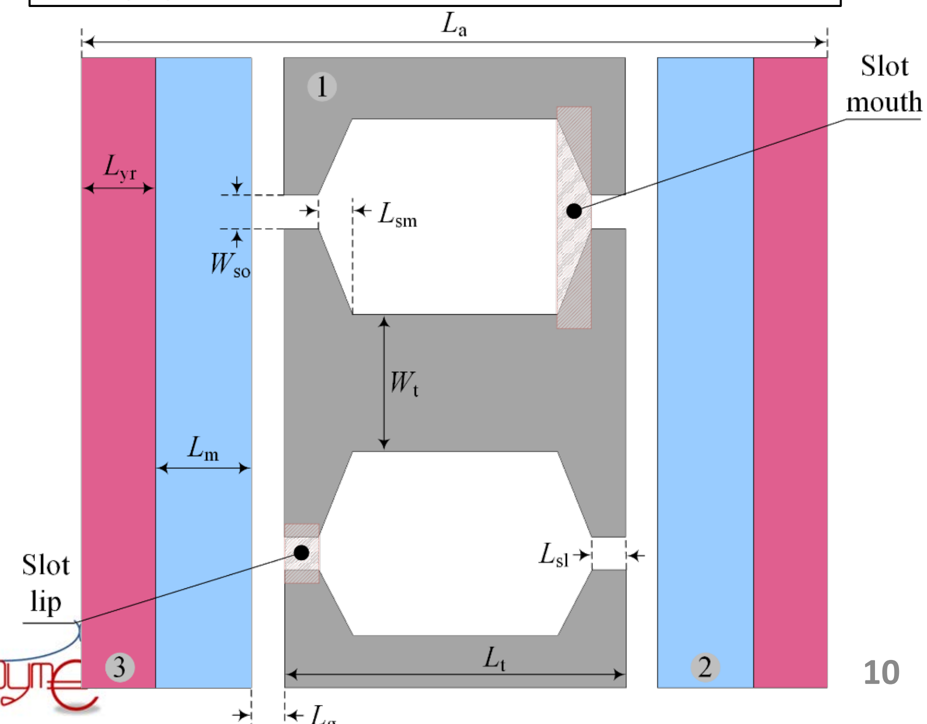
Design constraints

Number of stator slots	18
Number of rotor poles	16
Length of airgap	0.4 mm
Outer diameter of stator	260 mm
Gross slot fill factor	50%
Width of slot opening	1 mm
Depth of slot lip	2 mm
Depth of slot mouth	2 mm
Current density of coil	$4.5\ \mathrm{A\,mm^{-2}}$
Ratio of pole arc to pole pitch	1

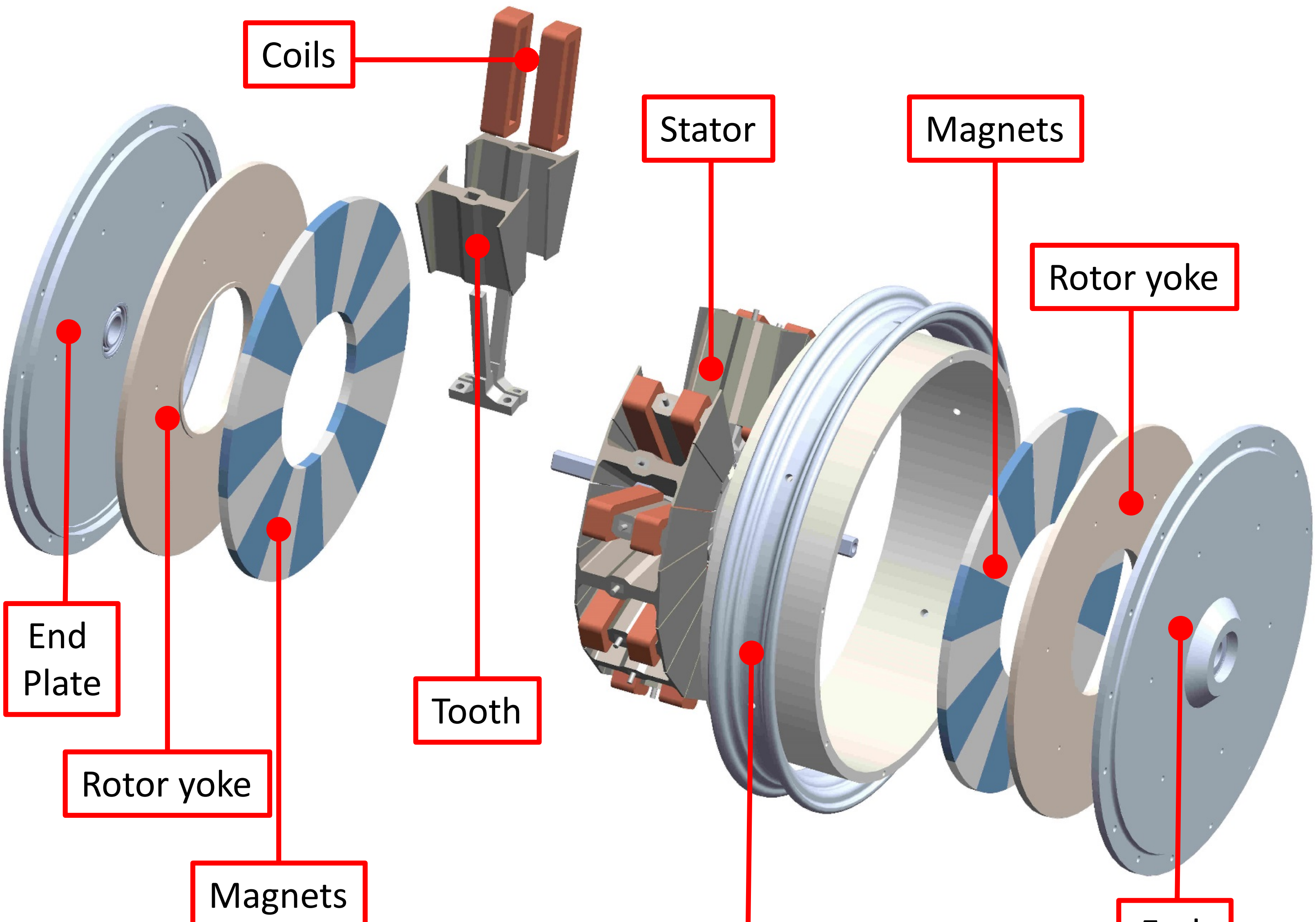
Optimised designs

Design	63	88	124	143	158	270
L_m (mm)	7.5	9.5	8	7	7	7.5
h (%)	0	10	5	0	5	10
λ_d (%)	50	52.5	50	47.5	45	47.5
L_{yr} (mm)	7	7	7	8	8	8
W_t (mm)	11.3	11.9	11.3	10.8	10.2	10.8
N_c	24	24	24	28	22	22
D_{ct} (mm)	2.8	2.8	2.8	2.6	2.8	2.9
L_t (mm)	32.4	30.6	32.2	32.6	33.4	32.6
L_a (mm)	62.2	64.4	63	63.4	63.9	64.4
R_{ph} (mΩ)	36	35	36	52	34	32
I_{ph} (A)	28.0	28.4	28.2	23.4	28.5	29.4
P_{cu} (W)	56.8	56.1	57.2	56.3	55.2	55.8

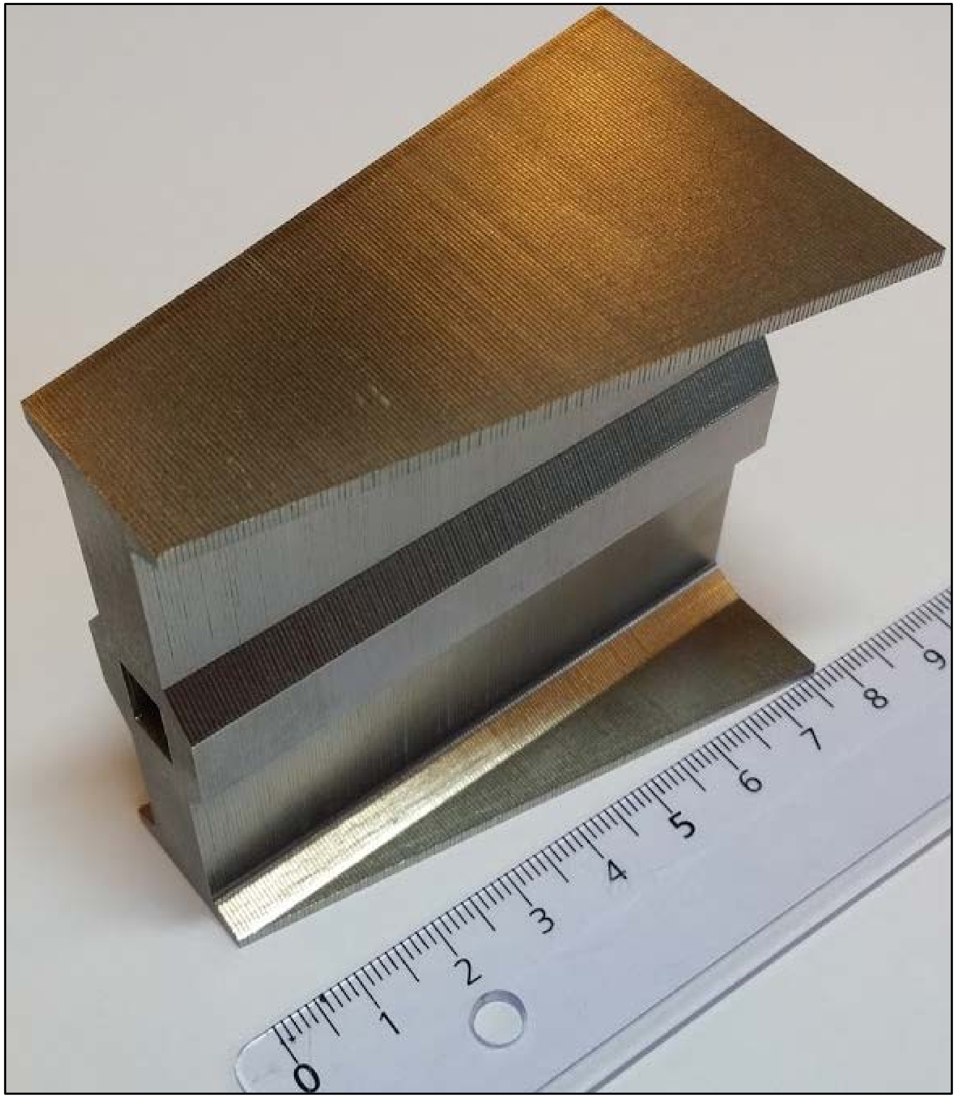


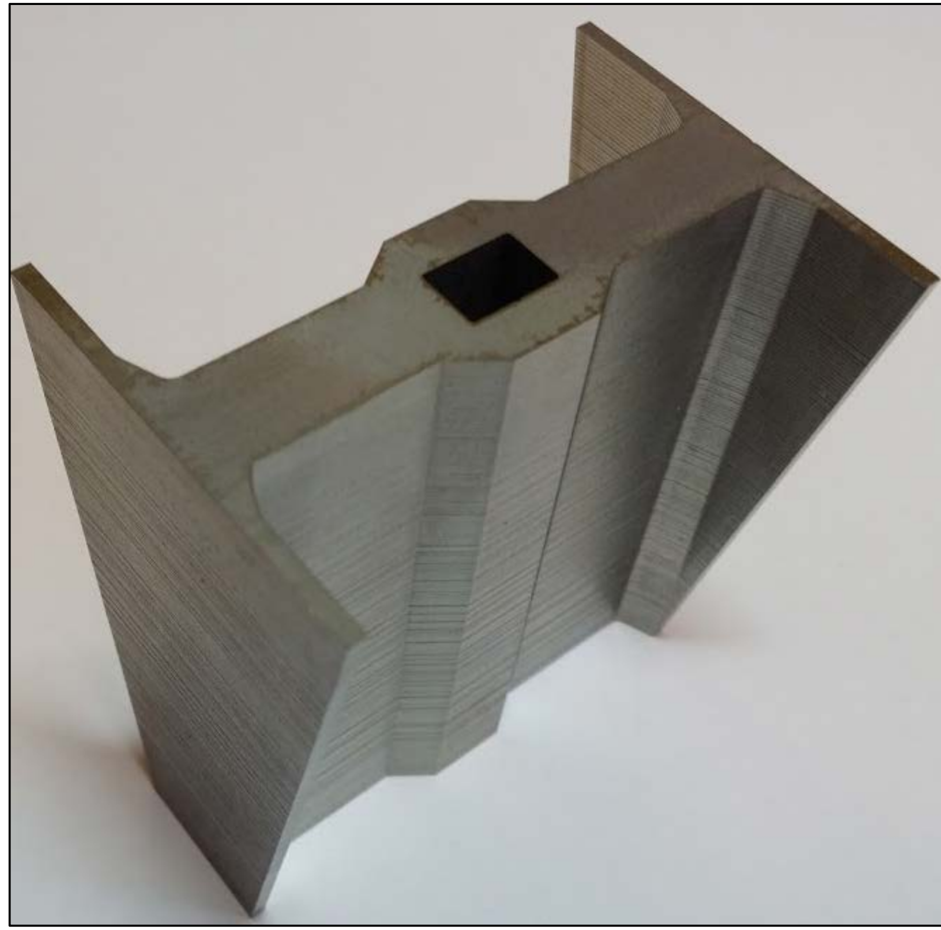


Mechanical assembly of the motor



Fabrication of motor - stator tooth





Material : M400-50A

Fabrication of motor - stator coils

Fabrication of motor – tooth mounting assembly

DTU

Tooth holder

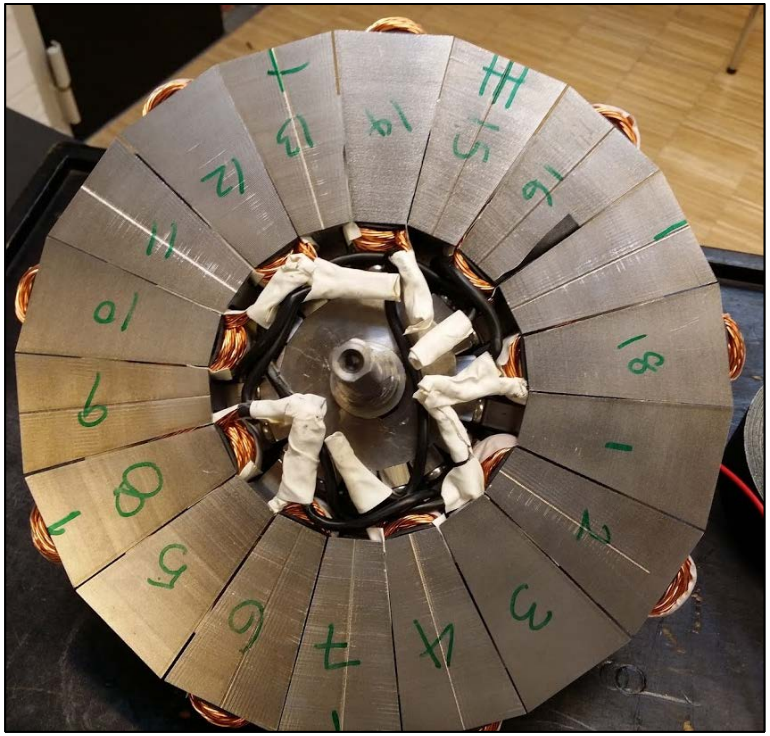
Tooth holder

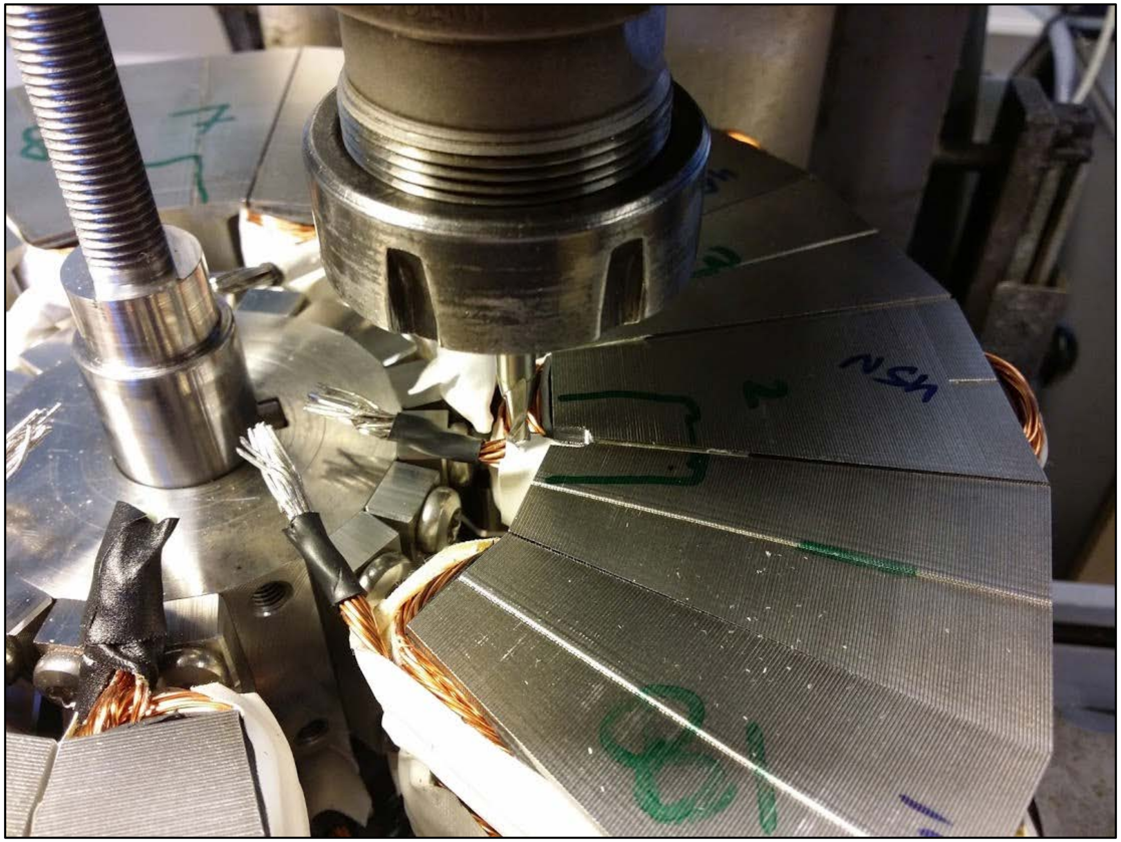
Shaft

SEVENTH FRAMEWORK PROGRAMME

Fabrication of motor – tooth mounting assembly

Fabrication of motor – Completed stator and rotor position sensor mounting





Fabrication of motor – Rotor yoke and magnet assembly

Completed motor on vehicle

Conclusion

- Introduction of improved energy density ferrite magnet based PM motors could improve the adoption rate of electric vehicles by offering low-cost powertrain
- DTU along with Nanopyme partners has fabricated and successfully completed first trial assembly of axial flux ferrite magnet motor for electric two-wheeler application
- In coming weeks DTU will fine-tune the motor assembly and integrate the motor to wheels of vehicle
- The on-board vehicle test of powertrain according to ISO 13064 standard is scheduled for October 2015. This will be followed by test bench evaluation of motor

Contact

Nenad Mijatovic
Postdoc
DTU Electrical Engineering
Phone +45 45 25 35 07
nm@elektro.dtu.dk

Muhammed Fasil
PhD student
DTU Electrical Engineering
Phone +45-45-25-36-51
mfasil@elektro.dtu.dk

Consortium

The research is partly funded by the European Community's Seventh Framework Programme under grant agreement no. 310516

www.nanopyme-project.eu