

Optika na krilu leptira



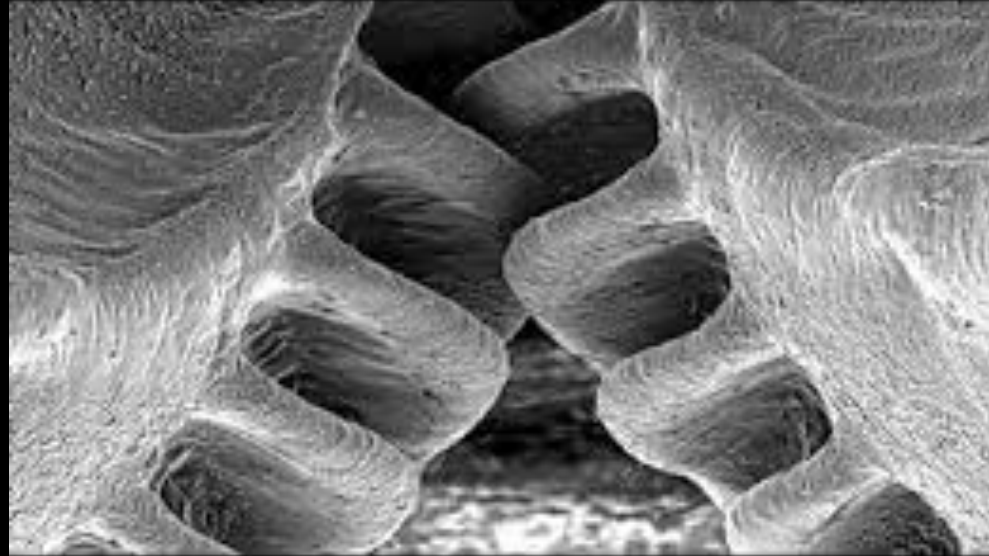
Dejan Pantelić
Institut za fiziku, Beograd

Fizika živog sveta

- Živi svet koristi sve što mu fizika pruža da bi preživeo
 - Mehanika, hidrostatika, hidrodinamika i aerodinamika, optika, ...
- Živi svet kao inspiracija
 - Biomimetika, bioinspiracija, funkcionalizacija, bionika, biofotonika, ...
- Insekti, kao najbrojnija grupa živih organizama (opisano oko 1 000 000 vrsta, pretpostavlja se da ih ima oko 5 000 000), predstavljaju široku oblast istraživanja

Prirodni zupčanik

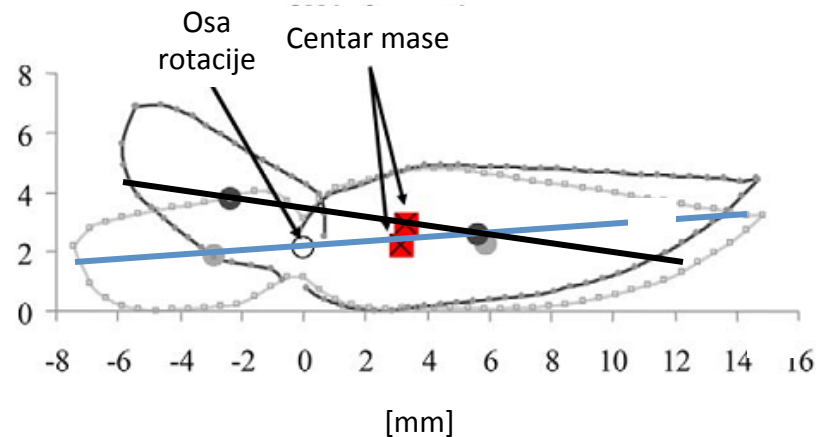
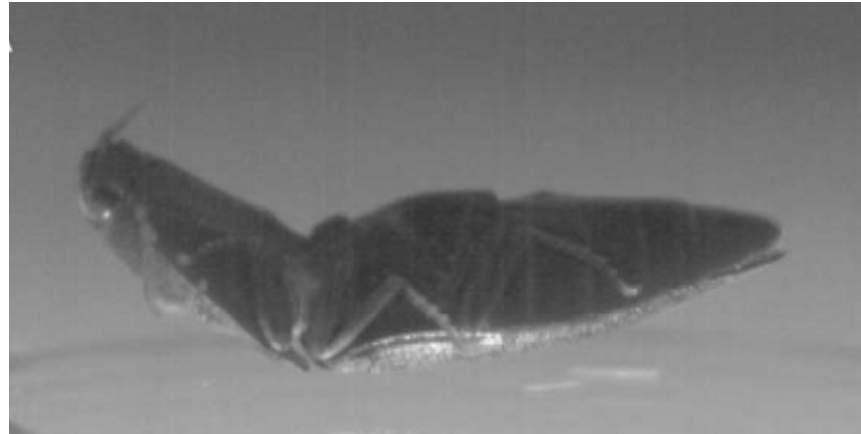
Issus coleoptratus, (Fabricius, 1781)



Burrows, M.; Sutton, G., "Interacting gears synchronize propulsive leg movements in a jumping insect", *Science*, **341** (6151): 1254–1256,

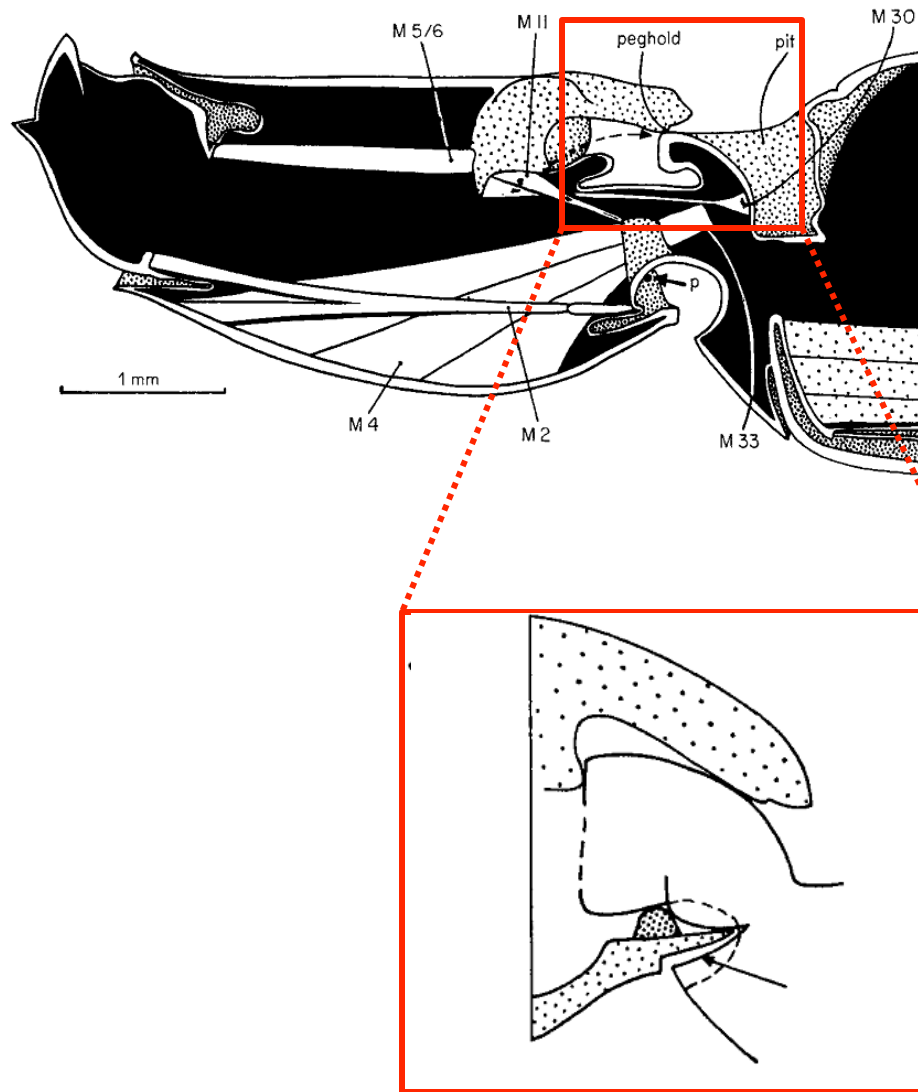
<http://www.smithsonianmag.com/science-nature/this-insect-has-the-only-mechanical-gears-ever-found-in-nature-6480908/>

Skok bez nogu – klik-buba (Coleoptera:Elateridae)



G. Ribak, D. Weihs, Jumping without Using Legs: The Jump of the Click Beetles (Elateridae) is Morphologically Constrained, PLoS ONE 6, (2011) e20871:1-7

Skok bez nogu – klik-buba (Coleoptera:Elateridae)



M. E. G. EVANS, The jump of the click beetle (Coleoptera, Elateridae) - a preliminary study, J. Zool., Lond. (1972) 167, 319-336

Kretanje u živom svetu

Vrsta	ubrzanje [g]
Čovek	1.5
Skakavac	15
Springtail (Collembola)	100
Buva	245
Click beetle	380
Jumping mite (Arachnidae, Acari)	500
Mantid shrimp (morski račić)	200
Trap-jaw ant (<i>Odontomachus</i>)	2000

W. Gronenberg, Fast actions in small animals: springs and click mechanisms,
J. Comp. Physiol. A (1996) 178:727-734

Živi svet i ostale oblasti fizike

Hidrostatika

Adhezija

Hidrodinamika i aerodinamika

Termalni efekti

Akustika

Optika

Bioluminescencija



Klik-buba

Luciferin – Luciferaza

Lepdoptera – krila pokrivena ljuspicama

- dnevni - leptiri
- noćni - moljci
- Optika na krilu leptira
 - interferencija
 - difrakcija
 - rasejanje
 - fluorescencija

I ti, srce, s tugom tvojom
Otrgni se i poleti
I leptirom žarkim budi!

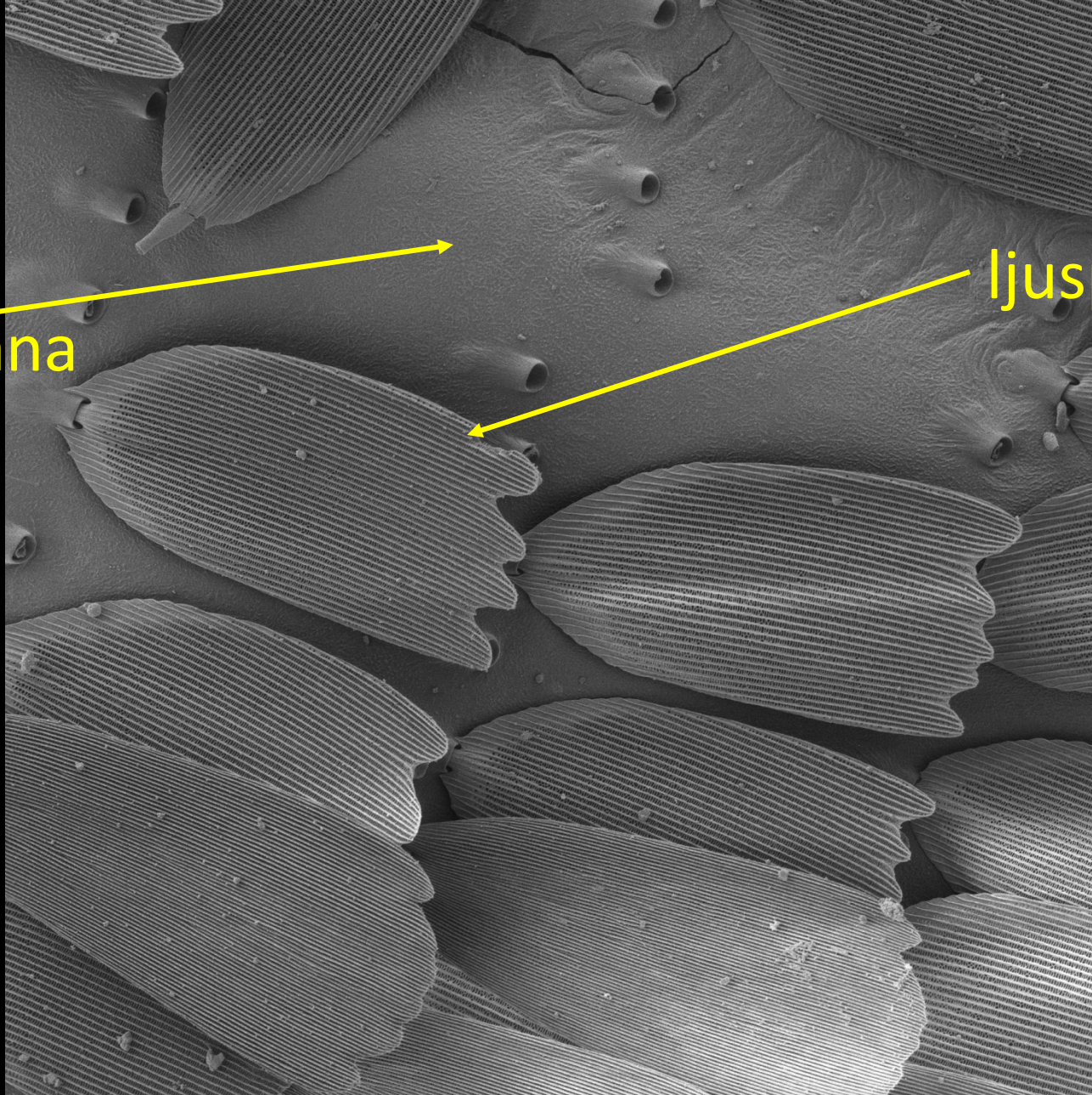
Boje, boje, boje...



pigmentne
strukturne

Krilna
membrana

Ijuspica



SEM HV: 3.0 kV

WD: 5.15 mm

MIRA3 TESCAN

View field: 241 μm

Det: SE + InBeam

50 μm

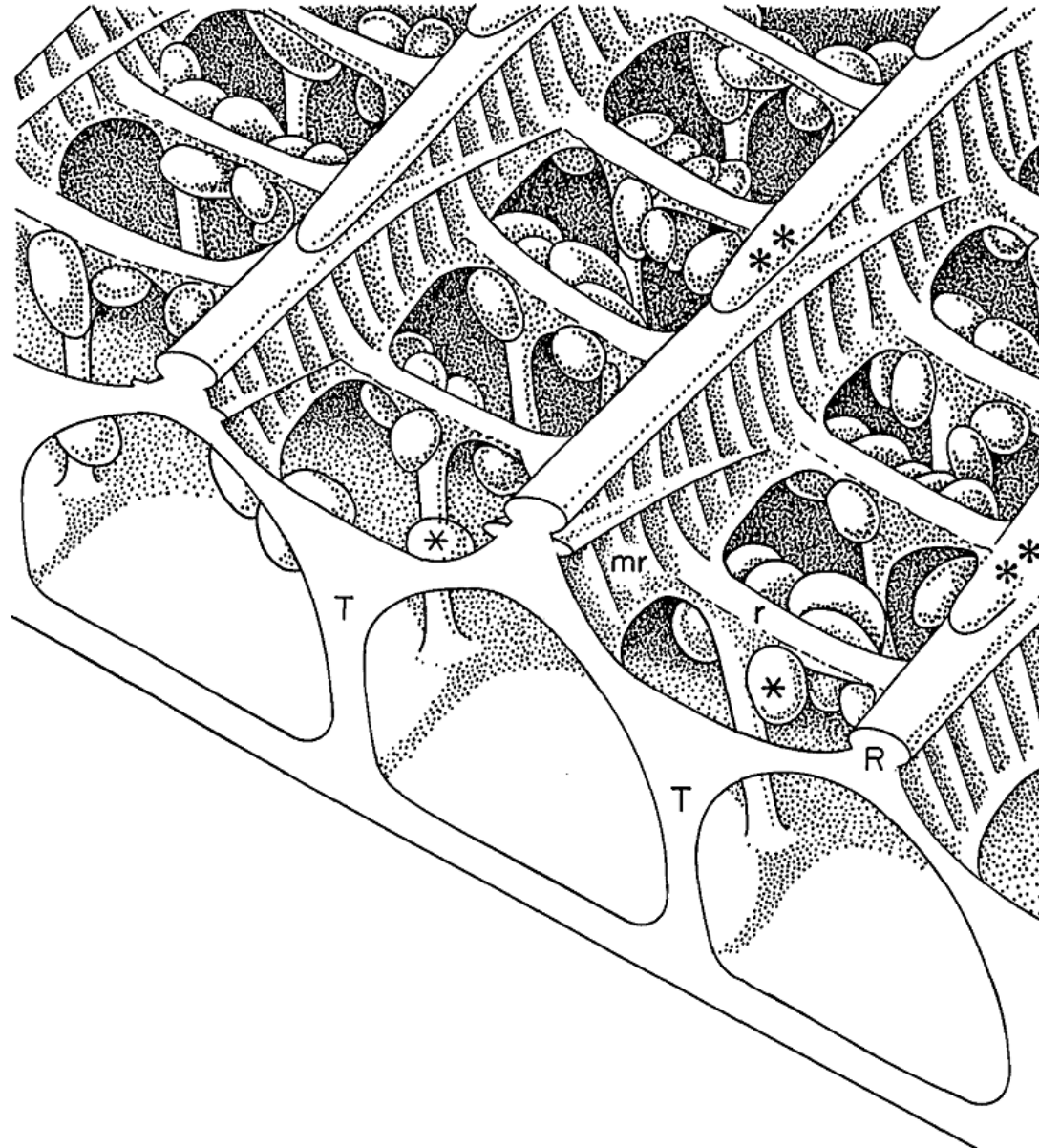
SEM MAG: 2.29 kx

Date(m/d/y): 07/03/14

Performance in nanospace



Opšta struktura ljuspica kod lepidoptera



Zovem se ljubičasto

Apatura ilia

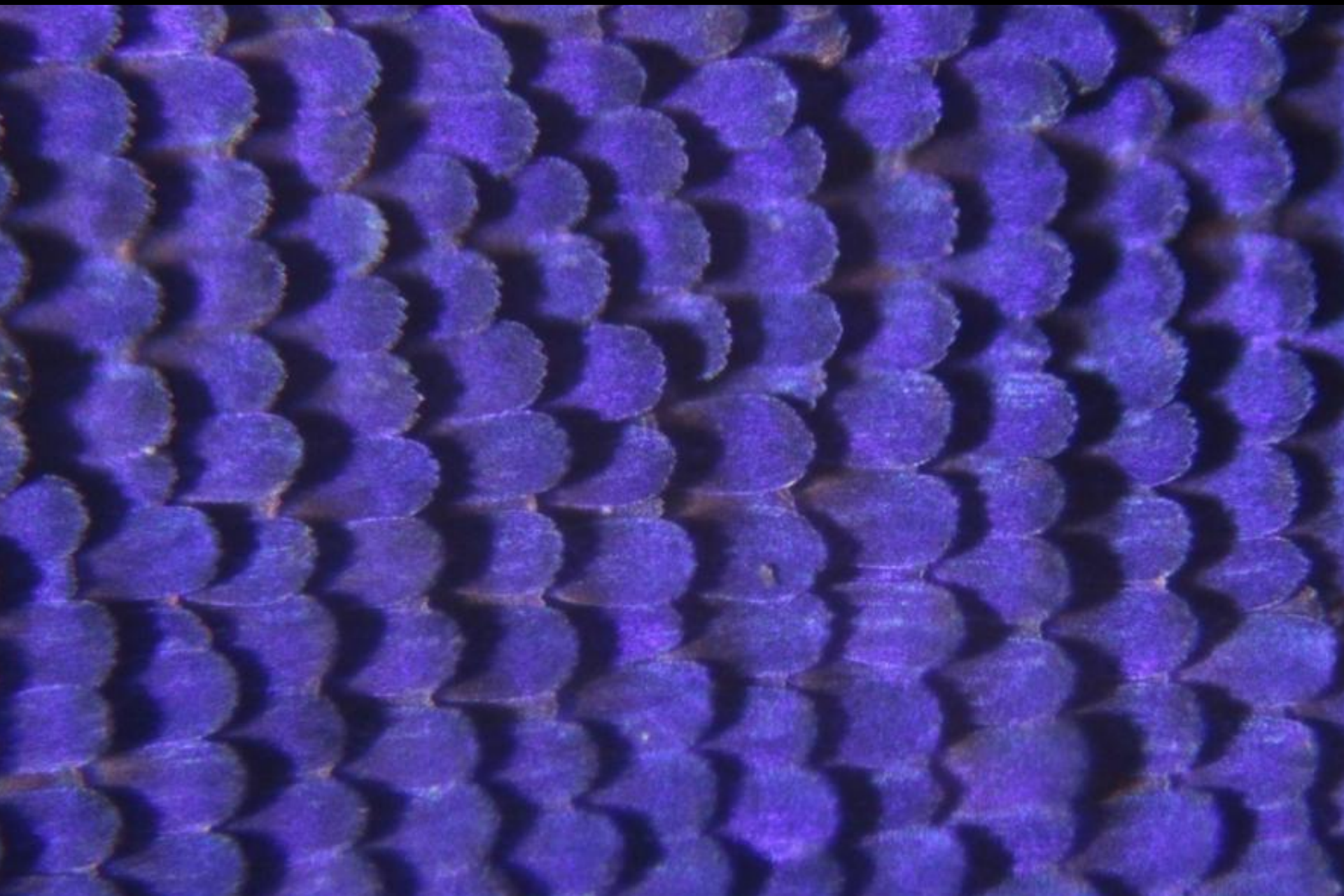


neiridescentno

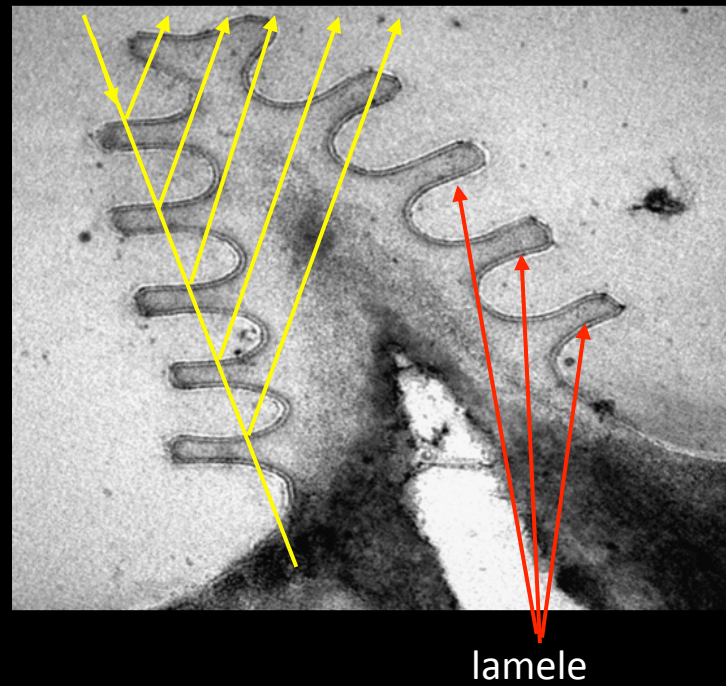
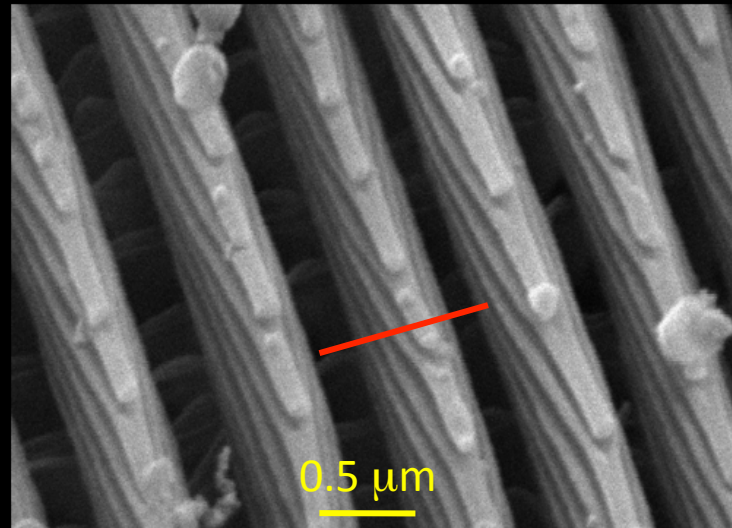
iridescentno

Iridescencija – promena boje sa uglom posmatranja

Ljuspice kao nosioci strukturnih boja



Ljuspica kao Bregova rešetka



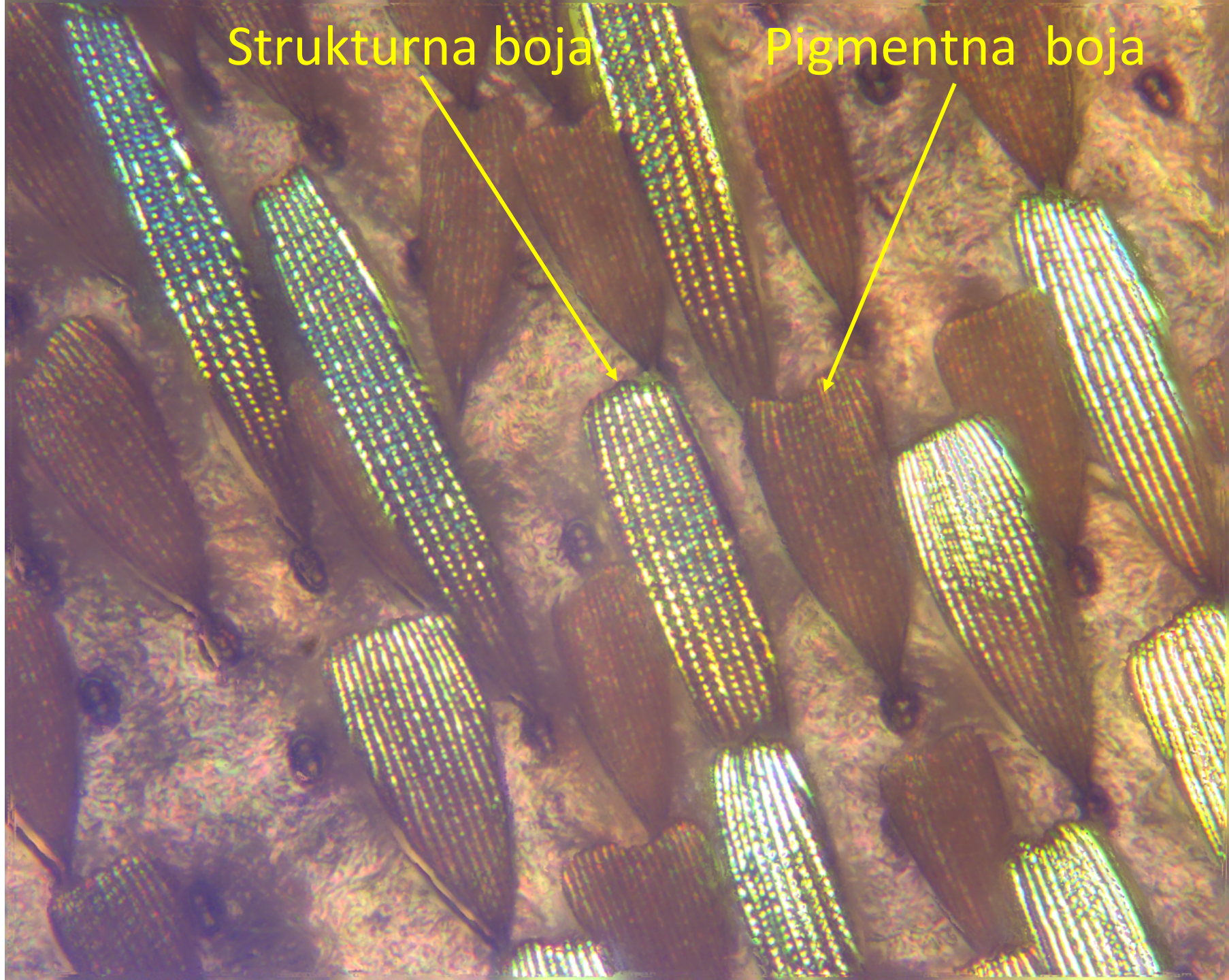
Zovem se zeleno

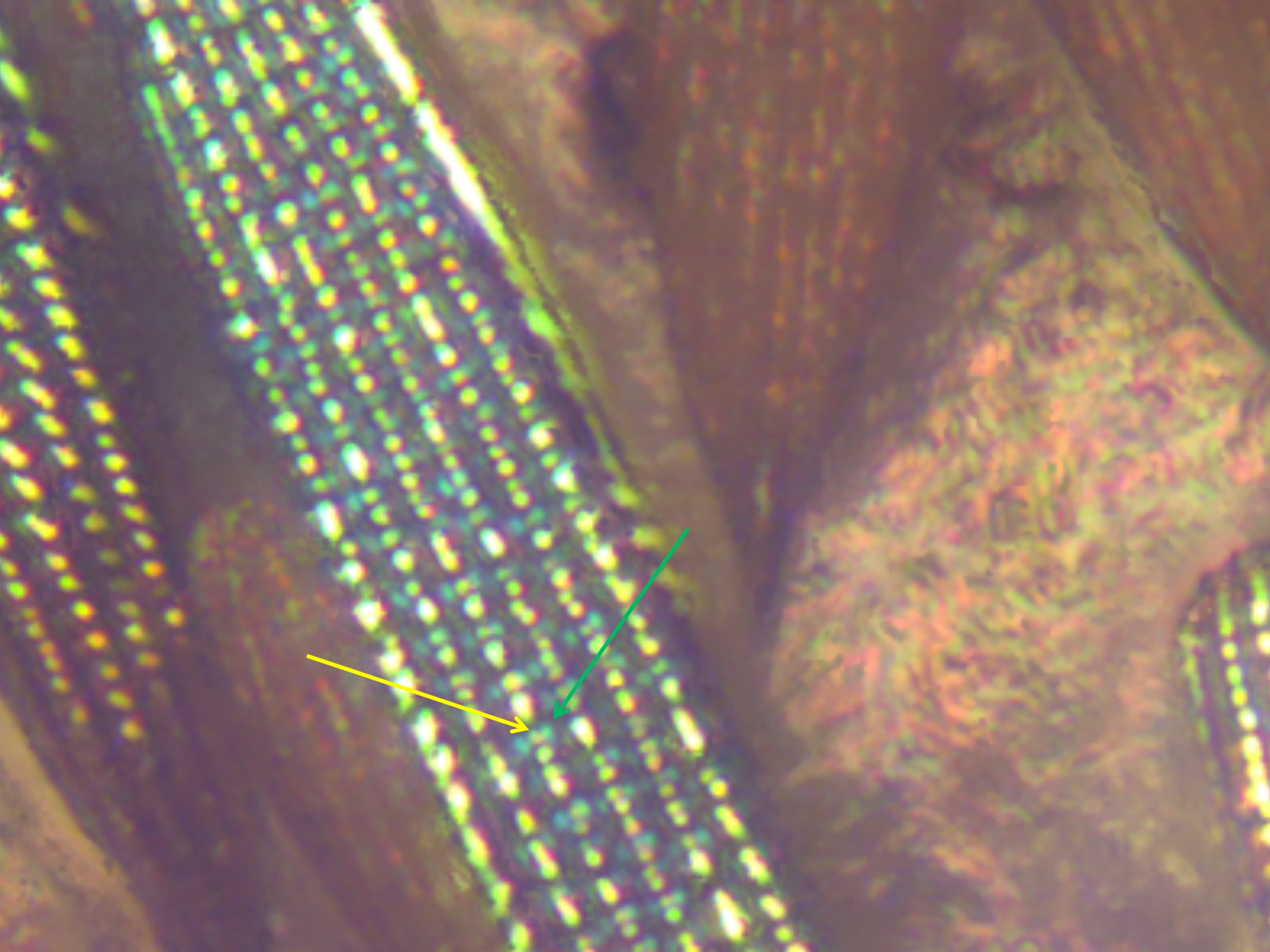
Jordanita globularie

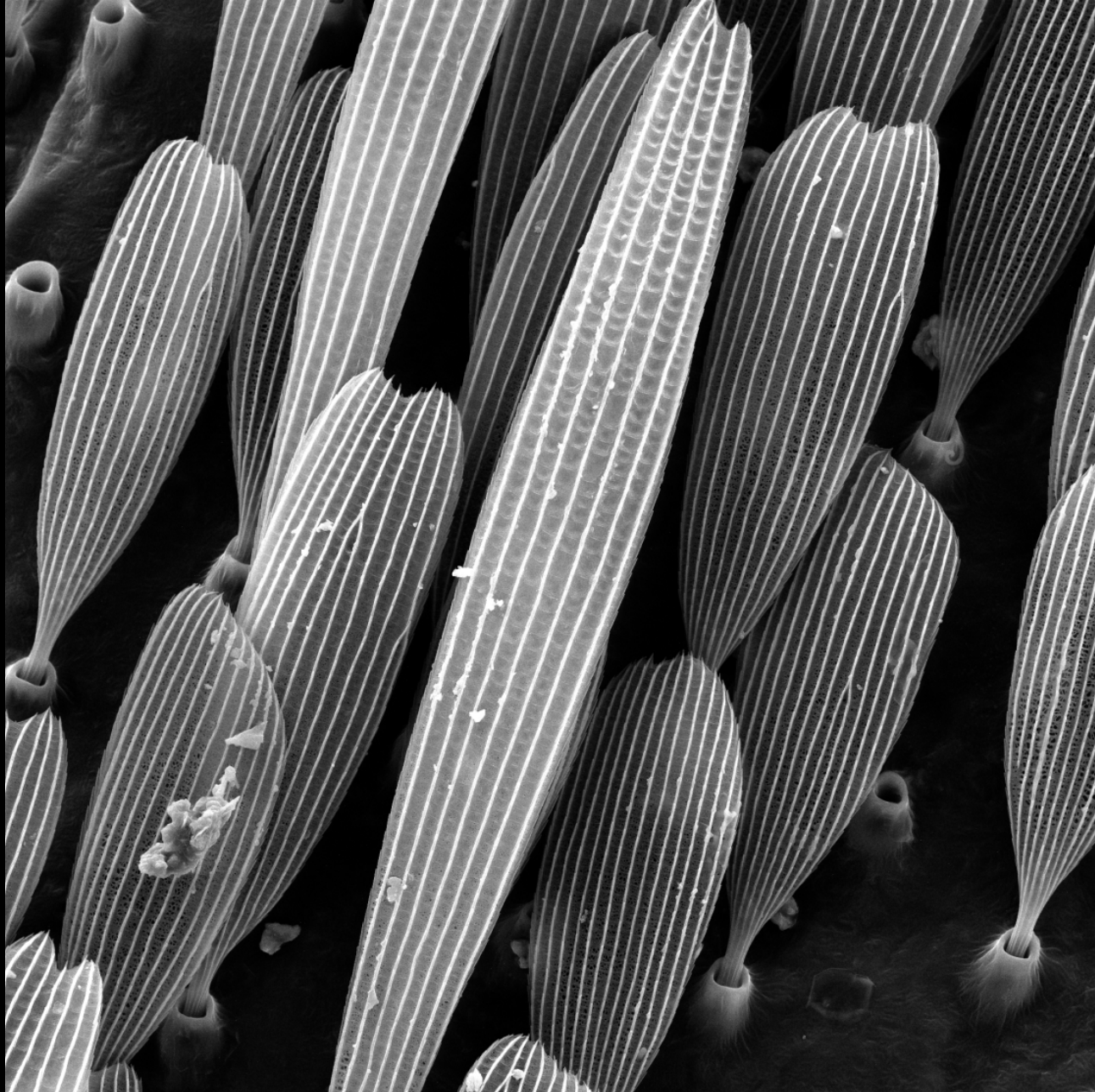


Strukturna boja

Pigmentna boja







SEM HV: 15.0 kV

WD: 16.44 mm

MIRA3 TESCAN

View field: 151 μ m

Det: SE

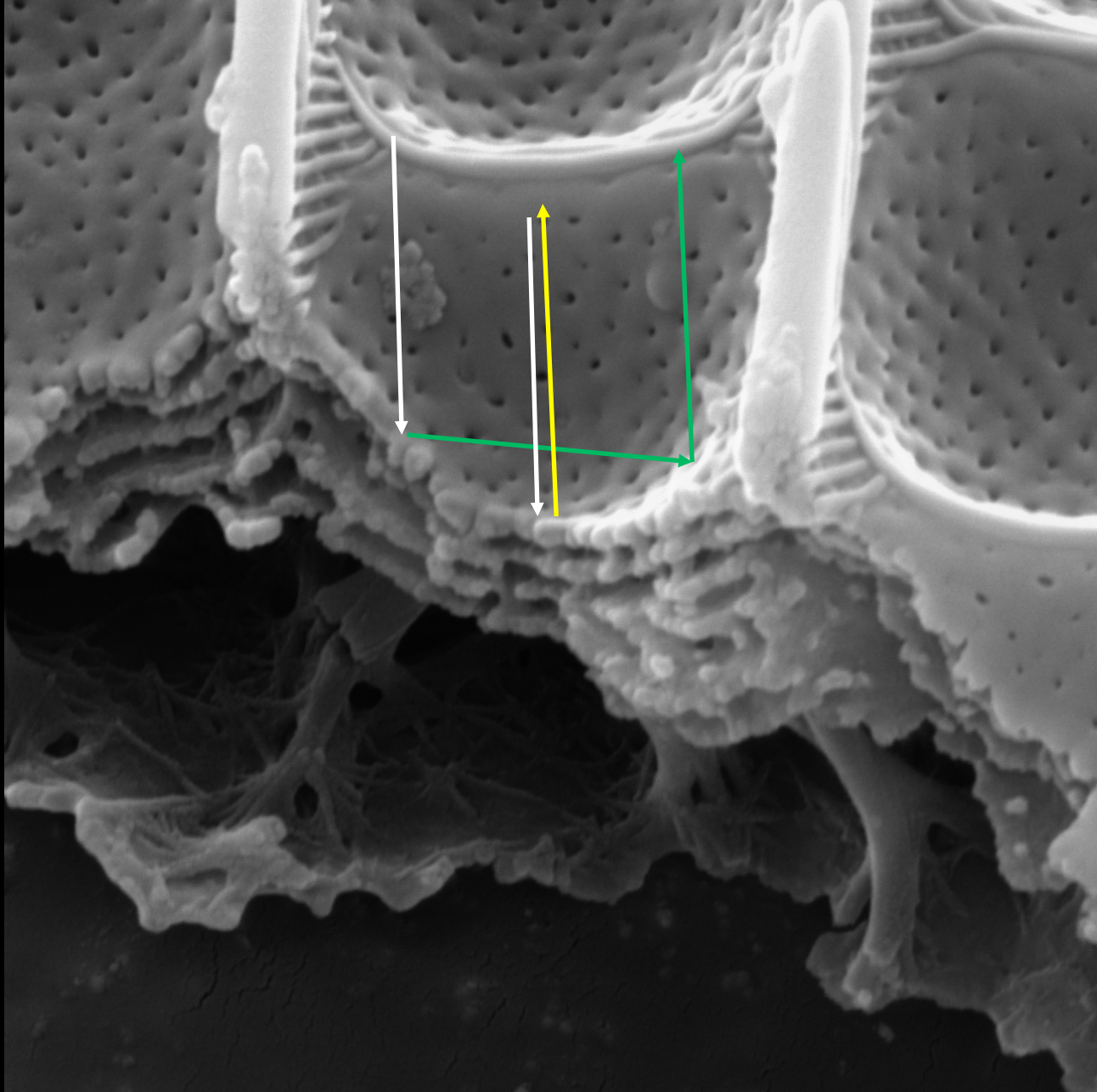
20 μ m

SEM MAG: 3.65 kx

Date(m/d/y): 06/27/14

Performance in nanospace

Unutrašnja struktura ljuspice



SEM HV: 15.0 kV	WD: 25.88 mm	 1 µm	MIRA3 TESCAN
View field: 5.79 µm	Det: SE + InBeam		
SEM MAG: 95.7 kx	Date(m/d/y): 05/22/14		

Performance in nanospace

Čemu sve to ?

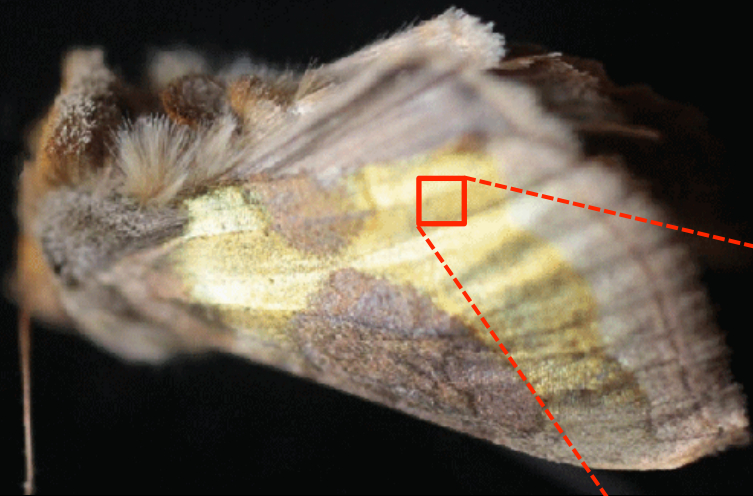
Biomimetika

Bioinspiracija

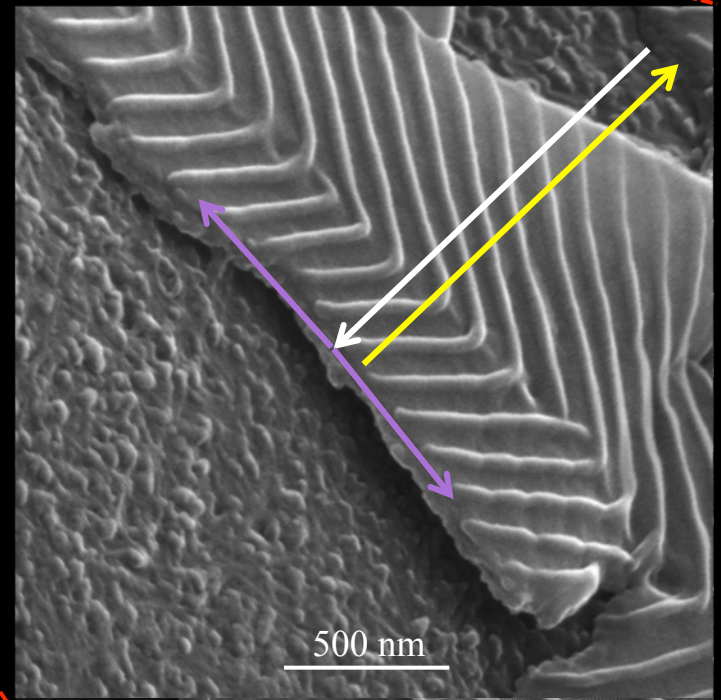
Funkcionalizacija

Zovem se zlatno

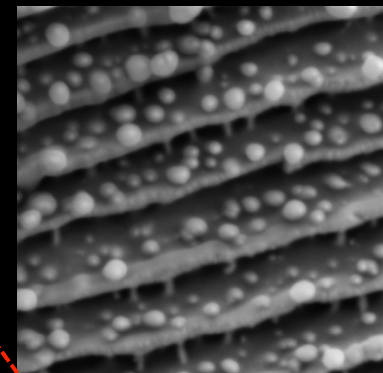
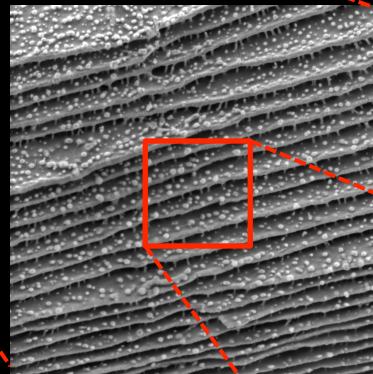
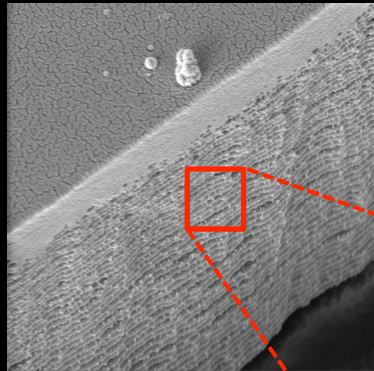
Holografaska mimetika zlatnog krila leptira



Diachrysia chrysitis
(Lepidoptera: Noctuidae)



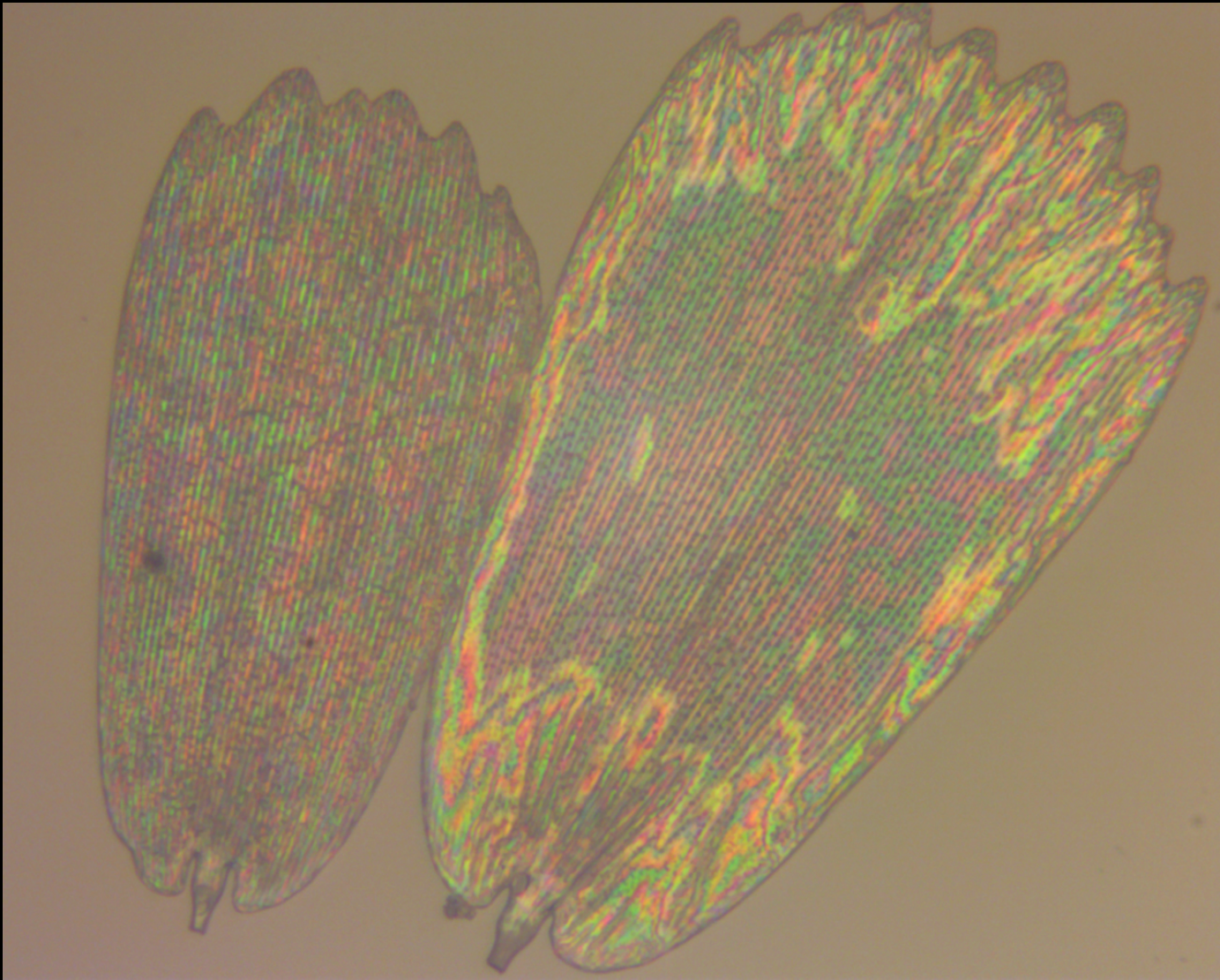
Holografsko generisanje slojevitih struktura na pululanu (polisaharidu biološkog porekla)



Holografsko generisanje slojevitih struktura na pululanu (polisaharidu biološkog porekla)

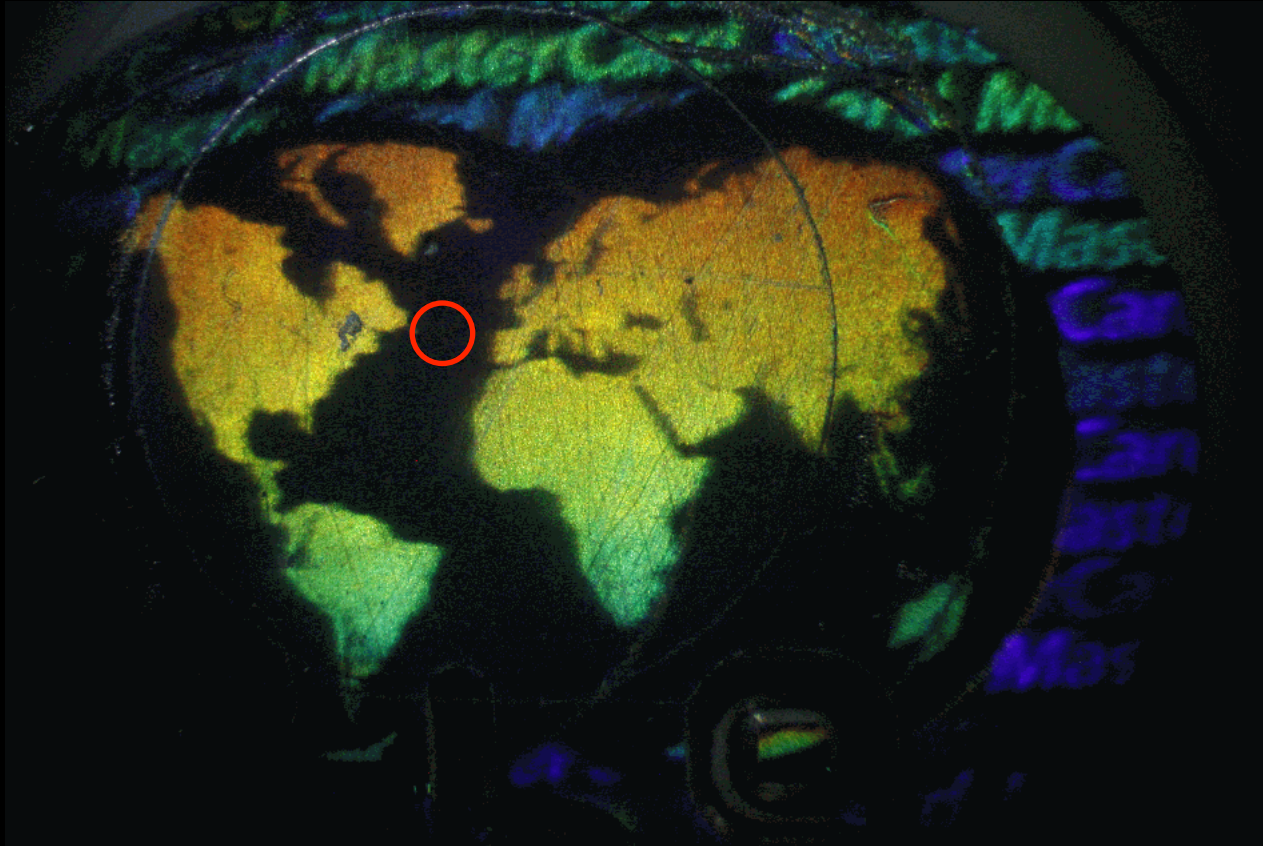


Jedinstvenost ljuspica leptira



Potrebno 10^{92} ljuspica da bi se našle dve identične

Ljuspica leptira na kreditnoj kartici



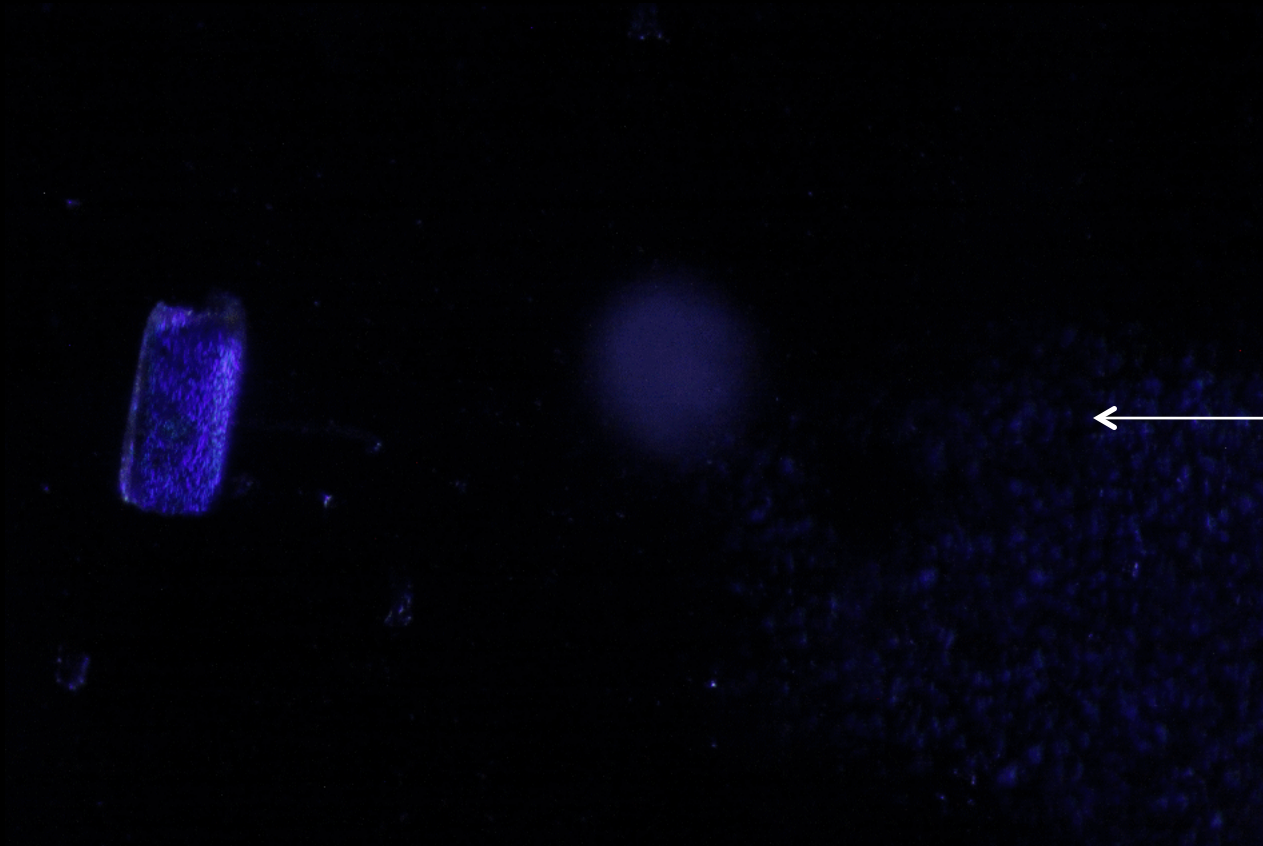
Ljuspica leptira na kreditnoj kartici



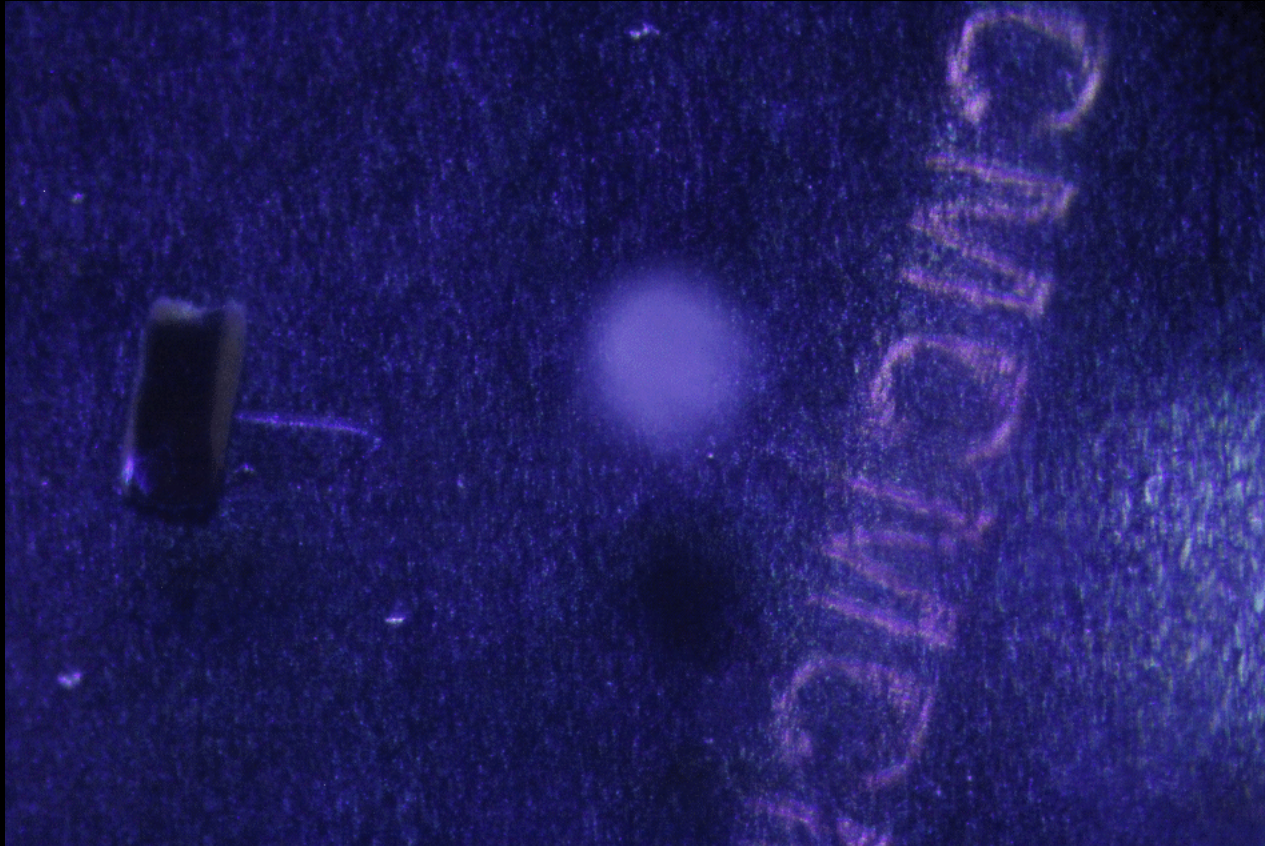
Ljuspica leptira na kreditnoj kartici



Ljuspica leptira na kreditnoj kartici povećano

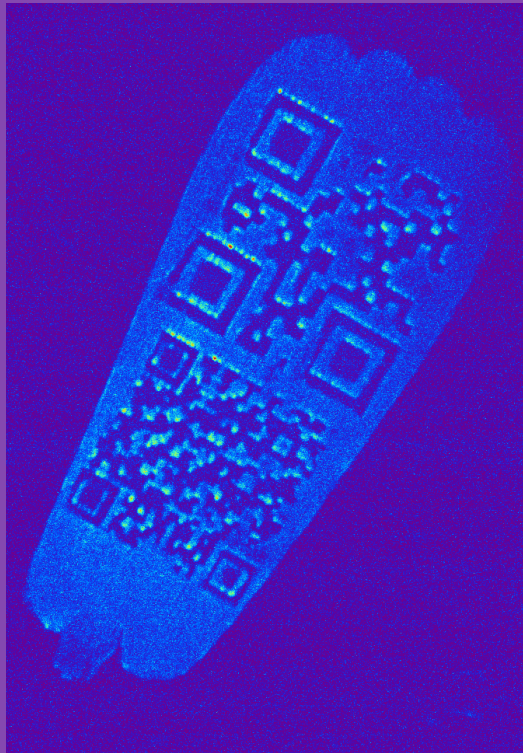
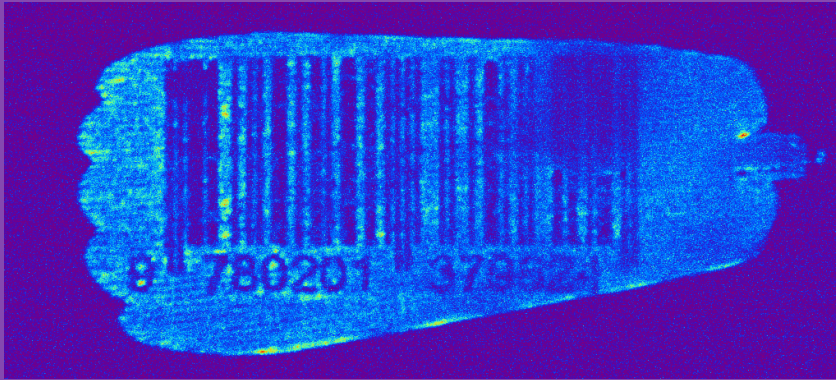


Ljuspica leptira na kreditnoj kartici povećano

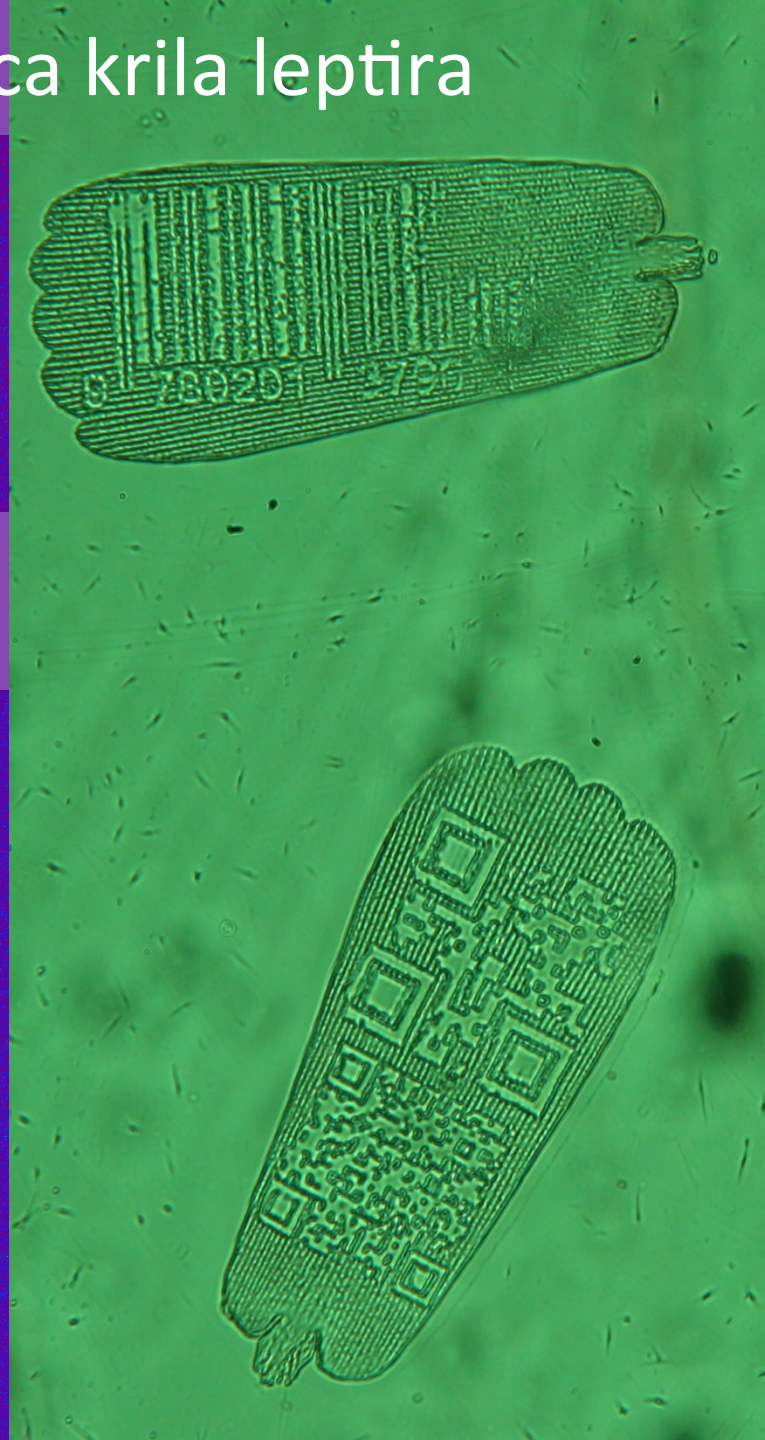


Lasersko sečenje ljuspica krila leptira

Fluorescencija

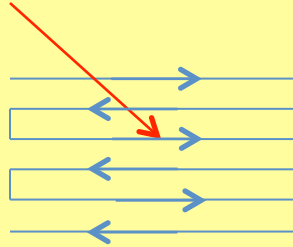


Transmisija

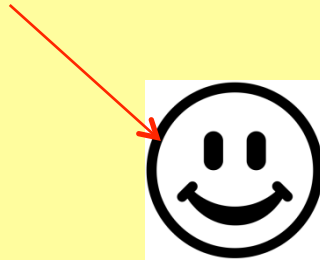


Nelinearna mikroskopija litografija i obrada materijala

Nelinearni mikroskop = konfokalni mikroskop sa laserom koji ima ultrakratke impulse

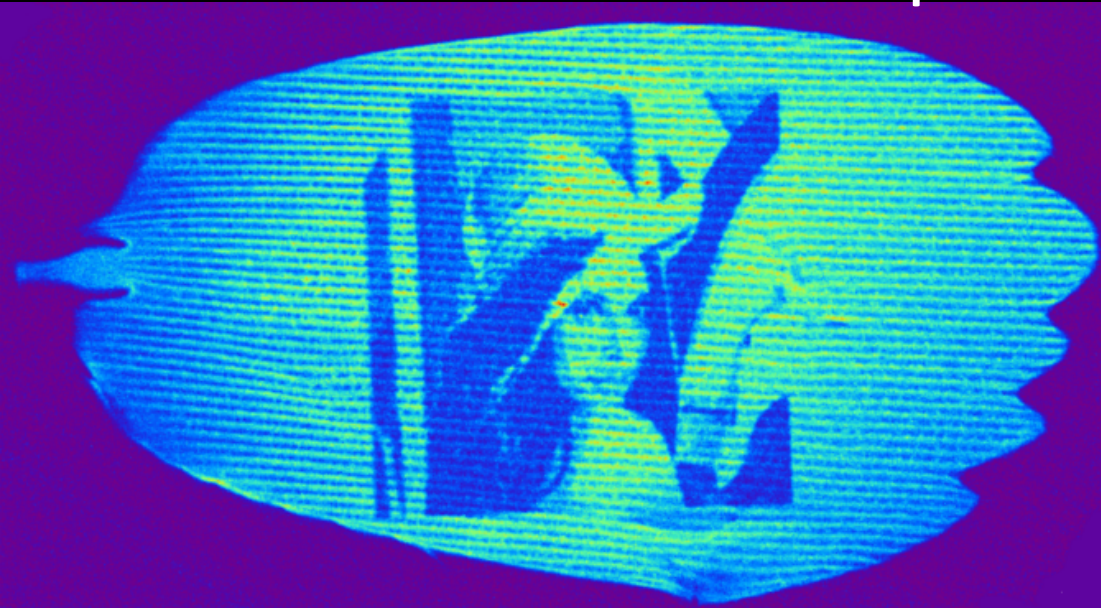


Nelinearna laserska litografija – iscrtavanje na fotoosetljivom materijalu pomoću ultrakratkih laserskih impulsa



Nelinearna obrada materijala = sečenje i bušenje materijala, laserska hirurgija

Selektivno gašenje fluorescencije ljuspica krila leptira

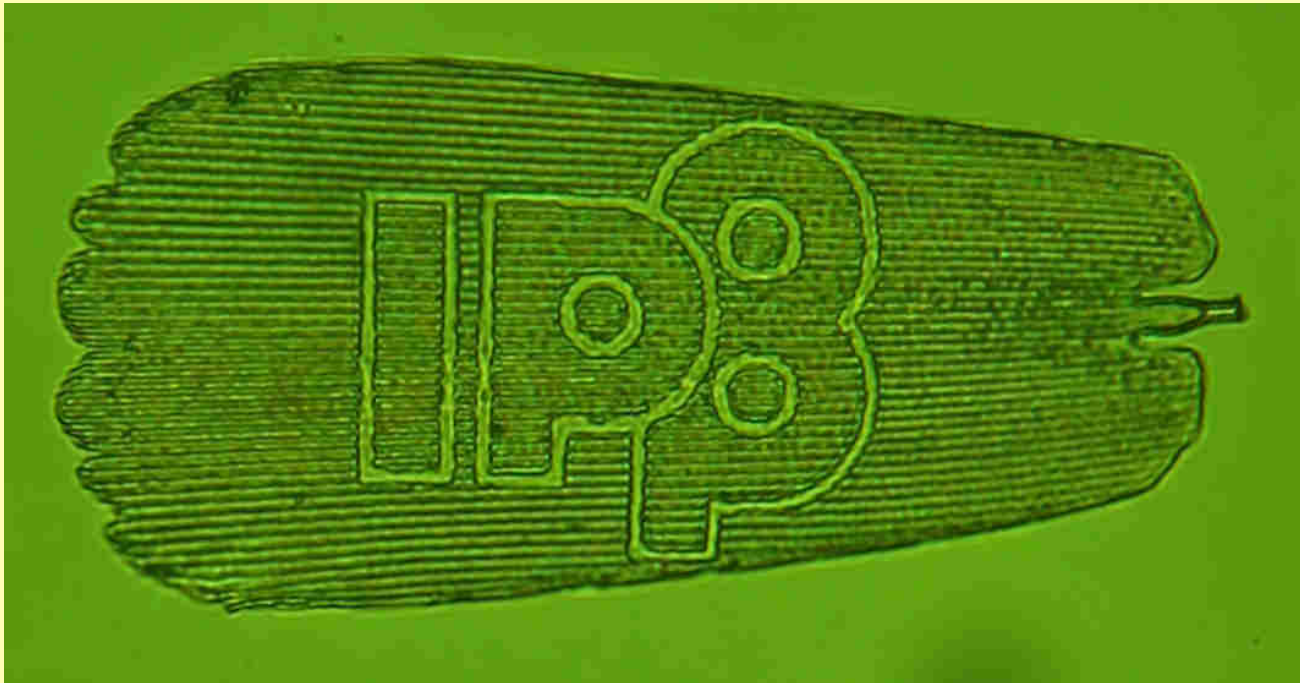


Lena



Institut za fiziku, Beograd

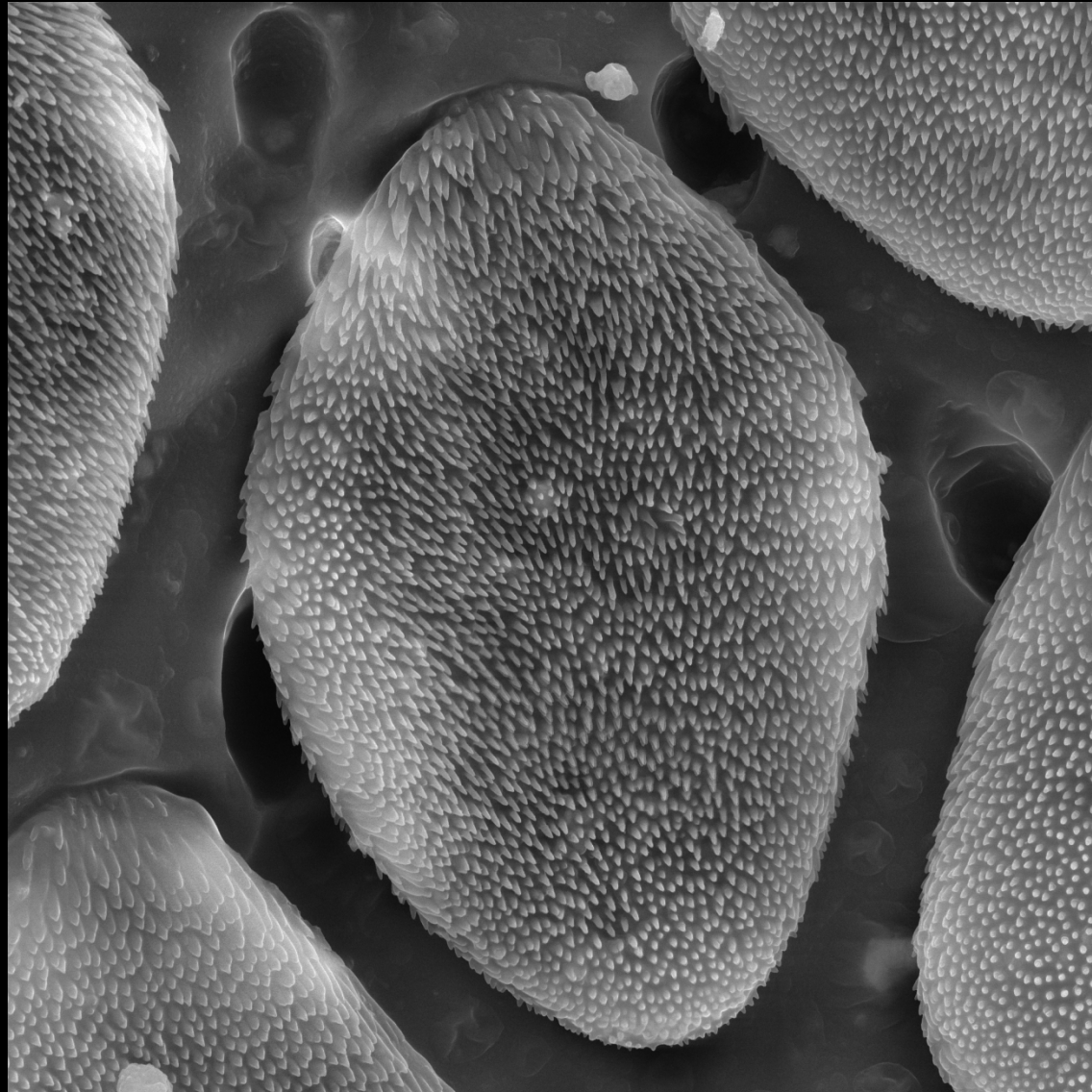
Institute of Physics, Belgrade



Teslagram®

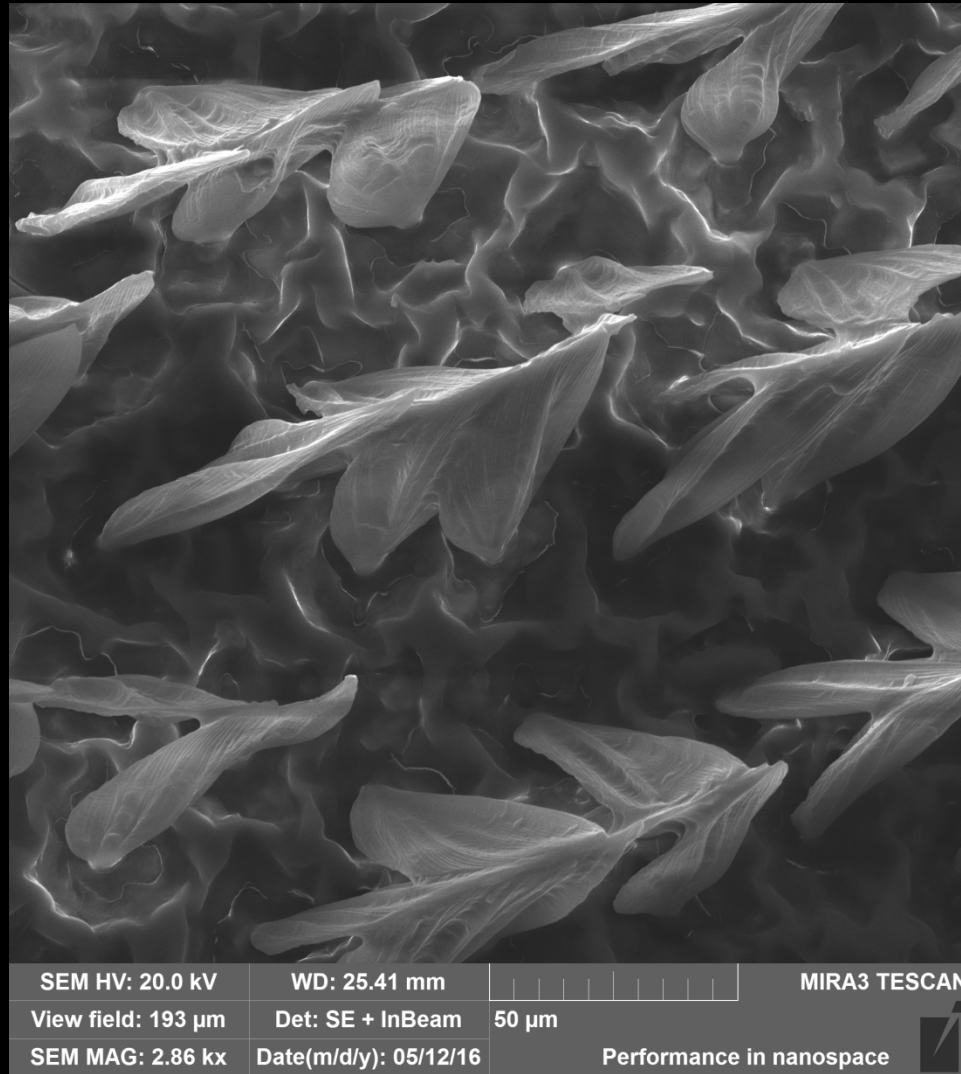
Šta dalje ?

Ljuspice *Hoplia argentea*

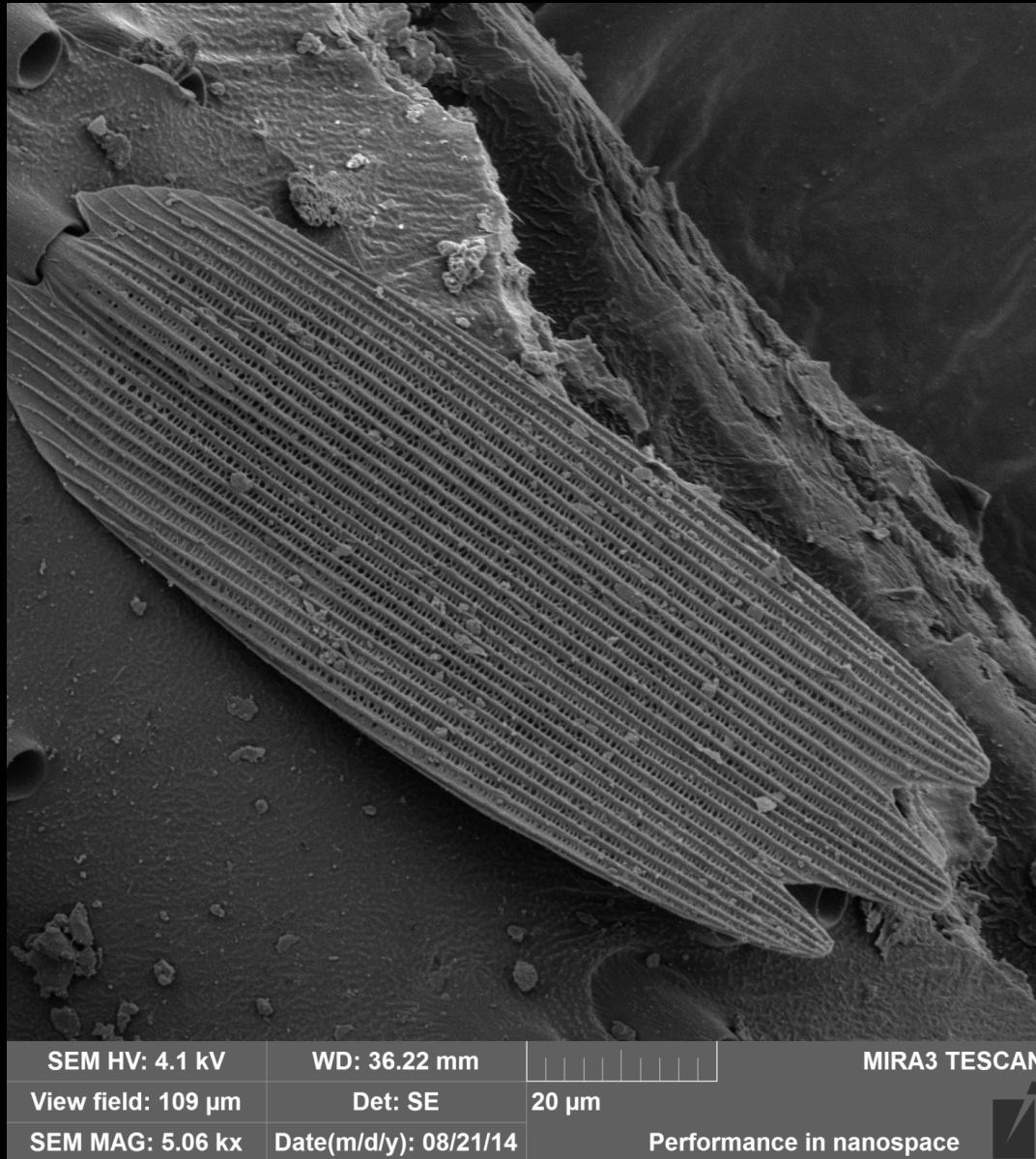


SEM HV: 20.0 kV	WD: 12.28 mm		MIRA3 TESCAN
View field: 85.7 µm	Det: SE + InBeam	20 µm	
SEM MAG: 6.46 kx	Date(m/d/y): 10/07/16		Performance in nanospace

Apsorpcione strukture Rosalia alpina



Ljuspica leptira kao senzor

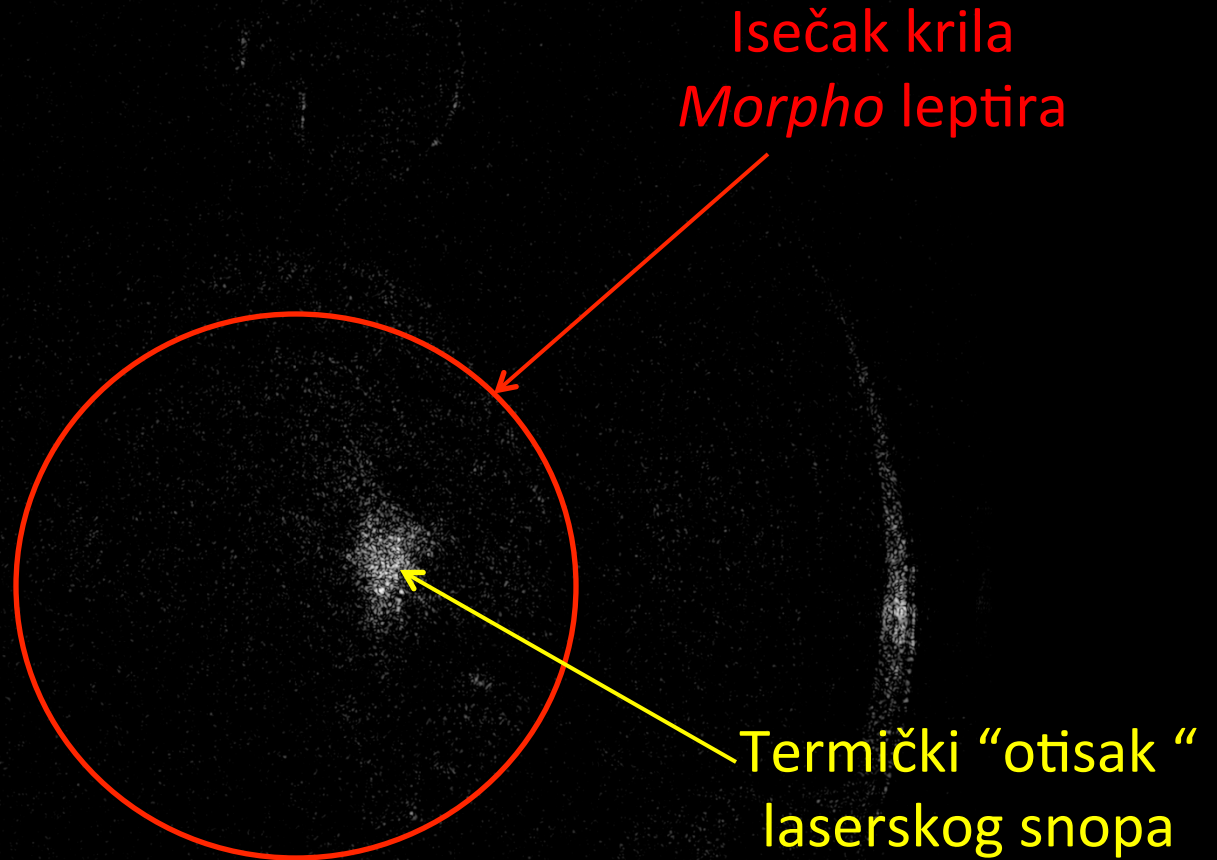


Nehladjene termalne kamere



Y. Zhao, M. Mao, R. Horowitz, A. Majumdar, J. Varesi, P. Norton, and J. Kitching, Optomechanical Uncooled Infrared Imaging System: Design, Microfabrication, and Performance, JOURNAL OF MICROELECTROMECHANICAL SYSTEMS 11, (2002) 136 - 146

Kamera na krilu *Morpho* leptira



Za sam kraj

“Float like a butterfly, sting like a bee”

Cassius Clay