Es gilt das gesprochene Wort!

Your Eminency, Ambassador Kotenev,
President Kutzler,
dear Professor Alferov,
Ladies and Gentlemen,

Technische Universität Berlin honors today

- a **scientist,** a titan of science, a scientist whose work has had more impact on modern society than most other living scientist,
  an impact, which will continue to grow during the remaining 90 years of this century and beyond

Technische Universität Berlin honors

- an **educator of generations of scientists**, who themselves are now important
- an **educator**, who in his present period of his life is a reformer of science and education at the RAS.

And we honor

- a pearl in a chain of pearls of **Russian-German cooperation in science and education**, a chain of pearls starting with **Leibniz and Peter the Great** 300 years ago.

Technische Universität Berlin was, and still is, for more than 2 decades your focal point for his cooperation with Germany, which made us together to the most successful team in the world, working in the field of **semiconductor nanostructures and nanophotonics**.

During the next minutes I will tell you the story, how

- Zhores Alferov met semiconductor physics and how
  outstanding intuition based on deep physical insight together with the systematic work of decades led to the achievements he is famous for now and for which he received in:

1971 the **Ballantine Gold Medal of the Franklin Institute**, followed
1972 by the **Lenin Prize,**
1978 by the **Hewlett Packard Europhysics Prize,**
1984 by the **State Prize of the USSR,**
2000 by the **Nobel Prize of Physics,**

2001 by the **Kyoto Prize,**

2002 by the **State Prize of the Russian Federation,**

2006 by the **Global –Energy-Prize,** to mention just a few, and

2010 **Dr. rer. nat h.c. of TU Berlin**

Certainly everlasting is the outer space.

Zhores Alferov was **born on March 15, 1930 in Vitebsk**, the fourth biggest city in East-Bjelorussia. The other famous former citizen of Vitebsk is **Marc Chagall**, who was born there (in Peskowatik) 47 years earlier.

His parents believed in socialism (as he does). Thus he received his first name in honor of the famous French socialist and author of **"J'accuse", Jean Jaurés**.

Zhores Alferov studied physics in Leningrad at the **then V.I. Ulyanov Electrotechnical Institute**, where he **graduated 1952**.

1953 he started to work at the **Physico-Technical Institute in Leningrad**, founded by **Abraham Ioffe** in the 20ties. This institute originally had tasks similar to the Physikalisch-Technische Reichsanstalt in Berlin. Ioffe himself was the first Ph.D. student of Wilhelm Röntgen in Munich.

It was Ioffe, who at the beginning of the 30ties initiated systematic studies of semiconductors at his institute.There **Zhenze and Kurchatov 1932** discovered the influence of doping with impurities on the conductivity of semiconductors (Zur elektrischen Leitfähigkeit von Kupferoxydul, Physikalische Zeitschrift der Sowjetunion). In the same year, in the same journal, **Frenkel and Ioffe** presented the first investigations of metal-semiconductor contacts, today called Schottky contacts.

Much of this early work was collected in the book "Fundamentals of Modern Physics" by Ioffe, which probably attracted Zhores Alferov sufficiently to enter the world of semiconductors.

Thus the fundamental direction of his research until today was defined at the beginning of his career in 1953, 57 years ago.

Seven years later, in **1960**, another completely different direction of research created excitement and interest across the world, including Zhores Alferov: The first demonstration of laser action in ruby by **Theodore Maiman**, verifying Einstein's prediction of stimulated emission (1917), was followed within 18 months by the demonstration of gas lasers and semiconductor diode lasers based on GaAs homojunctions. Solid state and gas lasers from the very beginning operated at room temperature, but semiconductor lasers did not.
They operated only at the temperature of liquid He, at 4 K. Gas and solid state lasers immediately found wide ranges of application. Not so semiconductor lasers, being judged at that time as useless.
The whole world, however, recognized at once how important **it would** be, to have room temperature semiconductor lasers. Teams at **Bell Labs, IBM, RCA,**… went into the race, but failed for quite a long time.

The problem - as we know now – was the p-n-homojunction. In a forward biased homojunction the charge carriers are widely spread in space at room temperature with low peak carrier density. In addition, there are enormous losses of the light emitted in the junction by recombination of electron and holes, since a gain-guided structure guides light only weakly.

At that time a new subject appeared in the life of Zhores Alferov: **The heterojunctions**.
Heterojunctions had appeared on the horizon already in the early days of electronics, starting **1951** with theoretical proposals by **Shockley, Kroemer** and others for improved transistors. Single heterostructure were tried for laser action observed up to 77 K, an enormous progress as compared to 4 K, but very academic still.

In **1963, Zhores Alferov and Rudi Kazarinov** from Ioffe Institute and **Herbert Kroemer,** independently from each other, proposed to confine carriers in a double heterostructure, leading to an increase of carrier density by several orders of magnitude in the confinement layer. He called it superinjection effect. But there was no practical realization.
The advantages of such a structure as pointed out a little later by Zhores Alferov in **1966**, would be efficient injection and localization of charge carriers in a material having a

narrower energy gap, surrounded by wide gap material, and efficient guidance of the emitted light by index of refraction steps at the heterojunction.
The proposal was a theoretical one and first attempts of experimental realization went into a wrong direction, as it happens often: Combination of indirect semiconductors and direct ones to form a heterostructure. Alferov's and Kazarinov's patent was then considered by some as paper work.
Then, suddenly material science and device physics merged. Zhores Alferov became aware that other researchers at Ioffe had successfully grown **a ternary compound AlGaAs**, lattice-matched to GaAs, but with a larger band gap.

He had the instinct to realize how important that progress was. Ideally perfect AlGaAs/GaAs/AlGaAs double heterostructures were grown by liquid phase epitaxy, lasers were processed and were observed to operate still at room temperature. In **1968**, results on **the first double heterostructure laser operating at RT** were submitted to Soviet Physics-Semiconductors. That was the breakthrough and ignited an explosion of work on many different applications which diffused, year by year, more and more, in our daily life.

Often we do not realize that there exists the same strategic device principle, the double heterostructure laser, which makes all these different systems work.
Examples for such systems are:

- laser printers,
- bar code scanners in supermarkets,
- the CD-ROM,
- optical communication systems, some form the basis of our internet explosion,
- or material processing systems, like welding or cutting machines.

The **economic impact** of present semiconductor laser based systems is enormous.
- The annual world-wide turn-over 2009 in photonics industry is **330 billion Euro**.
- Europe employs about **300.000 people** in this sector.
- The cumulated **annual growth rate is 7.6 %** for the last 10 years, the highest for any industry.

The story of scientific achievements of Zhores Alferov with impact on society is, however, far from complete. Zhores Alferov, in **1967,** already started to discuss the **first applications of such structures for electronic devices**.

Then, in **1970,** he presented the **first solar cells with efficiency >30 %** based on heterojunctions. Soon the Soviet Space Administration became aware of these results, and in **1986** the Soviet space station MIR was partially powered by solar cells developed by Alferov and Andre'ev.

Other applications of the heterostructure principle lead him to propose the **hetero-bipolar transistor (1973**), nowadays a high-power and frequency enabling device, e.g. for satellite telephones, in some way continuing his work for the candidate degree when he had developed power rectifiers based on Ge and Si.
Finally, in **1992**, being both at the same time at the University of California in Santa Barbara, we developed a joint research program an semiconductor quantum dots, nanosize particles, for the active zone of optoelectronic devices. Quantum Dot Lasers today have the lowest threshold of any semiconductor lasers. Quantum dots are now used for amplifiers in local area networks, solar cells, nanoflash memories…. the story repeats in some way.

Ever during his career, Zhores Alferov also found the time and had the strength to devote himself to what we here in Germany call **public service**. He became **people's deputy of USSR** and then **member of the DUMA**, the Russian Parliament, is today its oldest member,

organizes symposia for Nobel Laureates on Science and Society and became in the last 10 years the driving force for innovations, probably a peaceful revolution, in the education of young people.

Named Academician in 1979 he was elected **Vice President of RAS** in **1990**, which he is now for 20 years.
He founded the **Department of Optoelectronics** at St. Petersburg State Electro-Technical University together with Tuchkevich and was Dean of the Faculty of Physics and Technology at the St. Petersburg Technical University.

A decade ago, he founded the **St. Petersburg Scientific and Educational Centre of the RAS**, since 1st of January 2010 called Academic University, the only educational institution of the RAS.

Here the best pupils of the Oblast at the age of 16 have a chance to pass the last school years in a lyceum, then get university education and finally pass to research at the same place. He is presently its **Rector** !

We are proud that you will become part of our university and faculty in a few moments, when you become our **Doctor honoris causa**.

I would like to conclude this laudatio by thanking all of you for your attention and by wishing you, Professor Alferov, and me continuing joy in inventing the future and in working together.