# PATENT SPECIFICATION

## Cold-Resistant Fiber Optic Communication System for Autonomous Mobile Robots

Patent No. US 11,847,392 B2

Filed: March 15, 2021

Issued: September 12, 2023

Assignee: Polar Dynamics Robotics, Inc.

## ABSTRACT

A system and method for maintaining reliable fiber optic communications in extreme cold environments, specifically designed for autonomous mobile robots operating in sub-zero temperatures. The invention comprises a thermally-regulated optical fiber assembly with a novel cladding composition and an active heating element that maintains signal integrity in temperatures as low as -40 C while preventing signal degradation from thermal stress and mechanical strain.

## BACKGROUND

[0001] Autonomous mobile robots operating in cold storage environments face significant challenges in maintaining reliable communications due to the degradation of traditional fiber optic systems at low temperatures. Existing solutions suffer from signal attenuation, mechanical failure, and reduced bandwidth in sub-zero conditions.

[0002] Current fiber optic systems typically employ standard silica-based cores with conventional cladding materials that become brittle and lose optical efficiency at low temperatures. This limitation has prevented the widespread deployment of high-speed optical communications in cold chain automation applications.

## SUMMARY OF THE INVENTION

[0003] The present invention provides a cold-resistant fiber optic communication system comprising:

- A modified silica core incorporating rare earth dopants for enhanced thermal stability
- A proprietary multi-layer cladding composition with elastomeric properties maintained at low temperatures
- An integrated micro-heating element array with temperature-sensing capability

- A smart power management system that optimizes heating efficiency
- A strain relief mechanism designed specifically for robotic movement in cold environments

## DETAILED DESCRIPTION

[0004] Core Composition

The optical fiber core utilizes a modified silica composition incorporating erbium and ytterbium dopants in precise ratios (0.01-0.05% by weight) to maintain signal integrity at low temperatures. The core diameter is optimized at 9.2 0.1 micrometers for single-mode operation.

[0005] Cladding System

The cladding comprises three distinct layers:

- Inner layer: Fluorine-doped silica with proprietary elastomeric additives
- Middle layer: Thermally-conductive polymer composite
- Outer layer: Protective jacket with embedded heating elements

[0006] Heating Element Array

The system incorporates a distributed network of microscale heating elements:

- Spacing: 15cm intervals along fiber length
- Power consumption: 0.1W/m at -40 C
- Response time: <500ms temperature adjustment
- Thermal distribution uniformity:  1 C

[0007] Control System

The integrated control system features:

- Real-time temperature monitoring at 100Hz
- Predictive heating algorithms based on environmental conditions
- Automatic power optimization based on robot movement patterns
- Fault detection and redundancy switching

## CLAIMS

A cold-resistant fiber optic communication system comprising:

a) A modified silica core containing rare earth dopants

b) A multi-layer cladding system with thermal management properties

c) An integrated heating element array

d) A control system for maintaining optimal operating temperature

The system of claim 1, wherein the core dopants comprise erbium and ytterbium in concentrations between 0.01% and 0.05% by weight.

The system of claim 1, wherein the heating elements maintain fiber temperature above -40 C with power consumption not exceeding 0.15W/m.

A method for maintaining optical signal integrity in cold environments comprising:

a) Monitoring fiber temperature at multiple points

b) Activating heating elements based on predictive algorithms

c) Adjusting power distribution based on robot movement patterns

## INVENTORS

- Dr. Elena Frost
- Dr. James Barrett
- Marcus Chen

## ATTORNEY OF RECORD

Sarah J. Thompson

Reg. No. 58,392

WILSON SONSINI GOODRICH & ROSATI

650 Page Mill Road

Palo Alto, CA 94304

## ASSIGNMENT

All rights, title, and interest in this patent are assigned to Polar Dynamics Robotics, Inc., a Delaware corporation having its principal place of business at 2500 Innovation Drive, Cambridge, MA 02142.

## GOVERNMENT RIGHTS

[0008] This invention was made with government support under Contract No. NSF-SBIR-2145789 awarded by the National Science Foundation. The government has certain rights in the invention.